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LAND APPLICATION

AS TREATMENT FOR HAZARDOUS WASTES

Dillon Consulting Engineers & Planners

LAND APPLICATION

AS TREATMENT FOR HAZARDOUS WASTES

A REPORT
PREPARED BY

DILLON CONSULTING ENGINEERS & PLANNERS

FOR THE

WASTE MANAGEMENT BRANCH
ENVIRONMENTAL PROTECTION SERVICE
ENVIRONMENT CANADA

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LAND APPLICATION AS TREATMENT FOR HAZARDOUS WASTES

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EXECUTIVE SUMMARY

In Canada, some 1 to 1.5 million tonnes of wastes classed as "hazardous" are expected to be generated annually.

It may be economically and logistically attractive to treat dilute organic or aqueous fractions of this by land application, since this technique uses little energy or storage volume per cubic metre of such wastes.

Wastes environmentally suitable for such treatment are those which can be rendered harmless either through biological degradation processes or physical/chemical processes such as adsorption by soil minerals. Many technically suitable streams exist, including sludges from wood preserving, tanning, paint manufacture, petrochemical and other sources. Land application of petrochemical waste is well developed, so this report deals primarily with the potential for land application of other hazardous waste streams.

The following are major factors to consider in treating wastes by land application.

- The site conditions are of primary importance, since land application depends on biological processes which are affected by temperature, moisture, and aeration. Soil chemistry, climatic and hydrogeologic factors must be thoroughly understood.

- The techniques and sciences used in land application are more similar to those employed in agricultural operations than to those used in conventional waste disposal,

and these skills must be integrated into the treatment operation. The land application operation will be unlikely to be successful until this is accomplished.

- The technique is most suited to destruction of aqueous biodegradable waste with "low" levels of undegradable contaminants such as heavy metals. Generally other means of disposal become more practical as the concentration increases; recovery, incineration, or landfilling for example.

- Hazardous waste land application has not been practiced in Canada to a significant extent. Before adopting landfarming as a disposal method, experimentation on degradability of the waste at the specific site will be needed to indicate disposal effectiveness.

SOMMAIRE - RECOMMANDATION

Au Canada, de 1 à 1,5 millions de tonnes de déchets classés dangereux peuvent être produites chaque année.

Sur le plan économique et logistique, il peut être attrayant d'épandre des fractions aqueuses ou organiques diluées de ces déchets, cette technique consommant peu d'énergie ou étant peu encombrante par unité de volume.

Les déchets qui, écologiquement, se prêtent à ce traitement sont ceux qui peuvent être rendus inoffensifs, soit par dégradation biologique, soit par des procédés physico-chimiques tels que l'adsorption sur les particules minérales du sol. Beaucoup de déchets font techniquement partie de cette catégorie, y compris les boues produites par les ateliers de préservation du bois, les tanneries, les usines de peintures, les usines pétrolochimiques et autres. L'épandage des déchets de la pétrolochimie est très perfectionné, de sorte que le présent rapport traite surtout des possibilités d'épandage des autres déchets dangereux.

Avant de passer à l'épandage des déchets, il faut examiner les principaux facteurs suivants:

- Les conditions locales sont de première importance, l'épandage reposant sur des processus biologiques qui subissent l'influence de la température, de l'humidité et de l'aération. Les facteurs pédologiques, climatiques et hydrogéologiques doivent être appréhendés.

- Les techniques et les connaissances qui servent à l'épandage ressemblent davantage à celles de l'agriculture qu'à celles de l'élimination ordinaire des déchets, et il faut y faire appel pour le traitment, sinon aucun succès ne peut être plausiblement escompté.

- La technique de l'épandage convient le mieux à la destruction des déchets biodégradables aqueux, peu concentrés en contaminants non dégradables tels que les métaux lourds. En général, d'autres moyens d'élimination s'offrent à mesure que la concentration augmente: récupération, incinération ou enfouissement, par exemple.

- Au Canada, l'épandage des déchets dangereux n'a pas été pratiqué sur une grande échelle. Avant d'adopter l'épandage comme méthode d'élimination, il faut vérifier la dégradabilité du déchet à l'endroit précis destiné à l'épanage afin de déterminer l'efficacité de l'élimination.

1. INTRODUCTION

The purpose of this study is to make recommendations regarding land application of hazardous wastes. The use of animal wastes as a soil supplement has a long history, and the assimilation of other degradable materials into the soil environment is also familiar. Where wastes are hazardous, however, any treatment method needs more planning, environmental control, and care. There is an ever-increasing awareness of the potential for chemical contamination of the environment, and hazardous wastes are now rightly perceived as threats that need informed and rigorous control. Marginal treatment methods are no longer acceptable, and well-defined restrictions are imposed on treatment methods to ensure long-term protection. In this context, disposal on land for hazardous wastes may appear to be no longer acceptable. Indeed, many waste-related problems at this time are due to failures of conventional landfills and subsequent migration of contaminants.

However, land application as a means of treatment, rather than as long-term containment process like landfilling, is a process that has a place in the spectrum of waste management technologies. Properly implemented, organic matter can be destroyed and inorganics immobilized by soil at the molecular level. While the result is not unique to land application as a treatment method, land application does have other unique properties that make it suitable for the disposal of certain wastes.

Some potential advantages are:

- land application consumes very little energy in the treatment of the wastes for which it is suited;

- the wastes do not ultimately consume space, as they would in a landfill, or even as incinerator ash does;

- costs may be much lower than other means of disposal.

Consequently, it is desirable to define the range over which hazardous waste land application is an environmentally sound option. This must be done considering the wastes existing in Canada and the varied climatic and geologic conditions throughout the nation.

This study examines various wastes and the potential environmental effects of treating them by land application. Noting that land disposal effectiveness has always been strongly dependent on local conditions, site-specific factors are considered in conjunction with the waste types to develop general principles for use of this waste treatment method.

2. OVERVIEW OF SCIENTIFIC PRINCIPLES AFFECTING LAND APPLICATION OF WASTES

2.1 General

The soil environment is a dynamic and heterogeneous medium which, managed properly, can serve as an effective treatment medium for many wastes. A well-operated land application program will retain and degrade chemical constituents in the soil surface. Decomposition of a given waste depends on the interrelationship of many factors, including the characteristics of the wastes (physical, chemical, and biological properties), climatic conditions, and soil properties. The important processes that contribute to waste degradation and reduction can be microbial, non-biological (chemical and photochemical) or physical (evaporation and volatilization). These principles are applicable to both hazardous wastes and those traditionally regarded as non-hazardous such as sewage sludge. Th feasibility of land application for a specific waste may be limited because of its properties with regard to degradation, fixation, or environmental effects.

2.2 Waste Characteristics

The characteristics that a waste must have to be considered for land application can be discussed under two general headings. First, the waste must be capable of effective treatment by soil-interaction mechanisms. Wastes that are suitable thus will tend to:

- contain low concentrations of toxic material;

- be aqueous dispersions of contaminant;

- contain organic materials as the principal hazardous contaminant;

- be below th below upper threshold concentrations for effective treatment by micro-organisms;

- contain no contaminants that will be mobile in the soil surface after treatment.

Secondly, the wastes must be suited for handling by land treatment techniques. This means they must be:

- non-flammable as applied;
- non-acutely toxic to operating crew;
- able to be handled by conventional sludge handling and cultivation methods;
- 'practically' applicable.

Section 3 identifies these criteria more fully, and Section 6 presents characteristics of three specific hazardous wastes. It is important to note that the following discussions are applicable only to wastes having characteristics which suit them to land application.

2.3 Climate Considerations

Climate is particularly important in the overall understanding of land application principles. In general, climate considerations may be summarized as follows.

- Temperature fluctuations severely affect biological activity. Increases of about 10°C will result in an approximate doubling of biological activity.

- Sustained periods of precipitation may prove a hindrance to vehicle activity in and around a land application site.

- If net precipitation exceeds net evaporation, runoff or infiltration of the site will occur. Figure 2-1 depicts the major pathways for water entering a site.

- Where wet periods are seasonal, changes in the water table may affect aeration of the soil-waste interface.

- Sludge application rates are based on precipitation/evaporation data (as will be explained in a following subsection).

- Other design criteria, such as storage and leachate collection, are a function of weather conditions.

2.3.1 Constraints Imposed by Climate

The land application of hazardous wastes is limited by the following factors:

- The rate at which waste can be applied while still maintaining aerobic conditions in the soil. This is affected by climatic conditions, particularly precipitation, as well as other factors such as:

  . method of waste application
  . soil drainage
  . soil characteristics, and
  . water content of the waste

- The number of days during the year when waste can be applied. This is dictated by weather conditions,

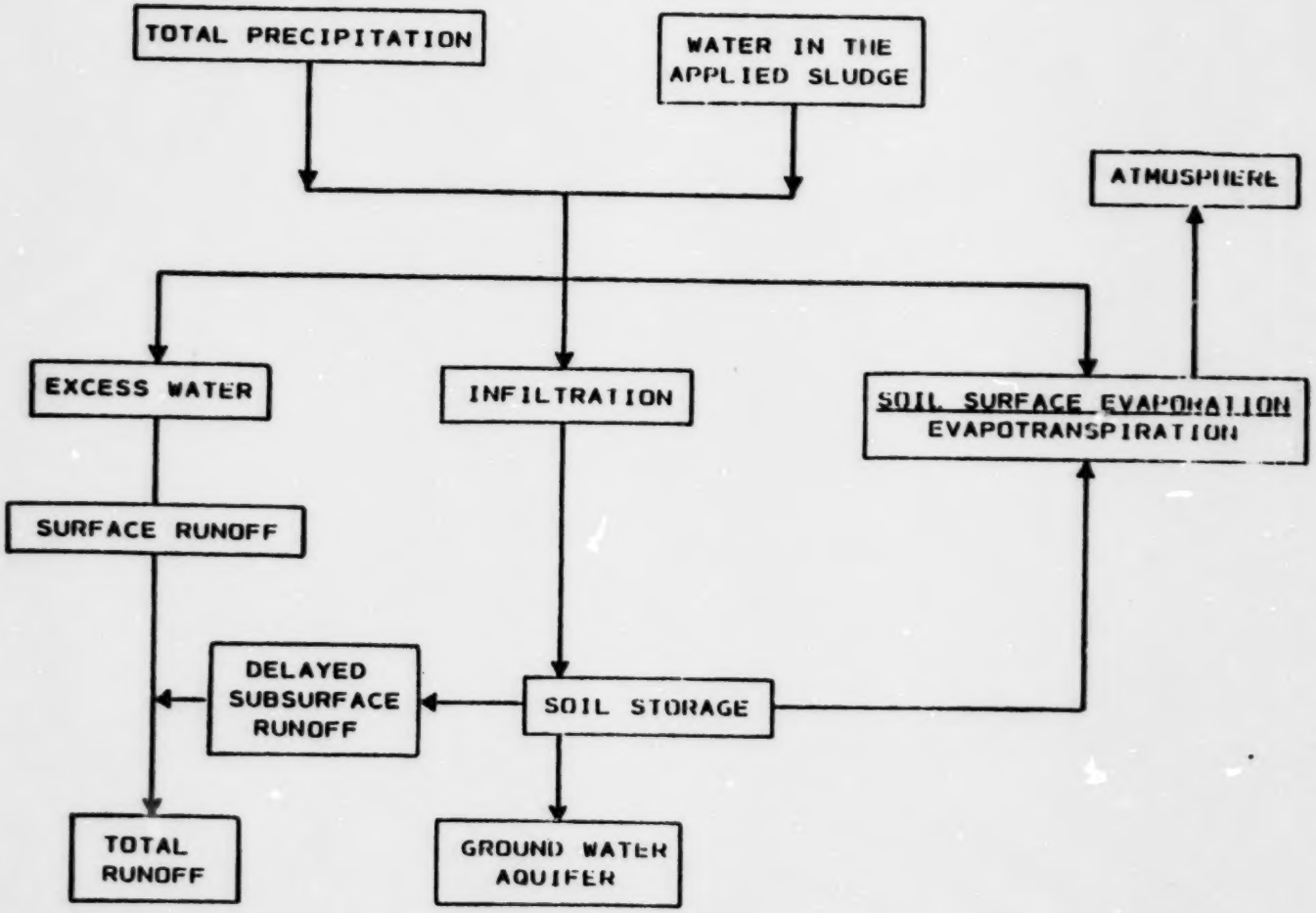

Figure 2-1. Fate of water received by landfarming site.

ability of the waste application equipment to operate with existing soil conditions, and equipment breakdown and maintenance requirements.

- Evaporation rate, if that is the design pathway for elimination of waste liquids.

2.3.2 Effect of Precipitation on Waste Application Rates

Annual waste application rates may vary drastically, depending on the moisture content of the waste and the local climatic conditions. Higher application rates are usually feasible where:

- the land application site receives dewatered waste;
- the waste is mechanically incorporated into the soil;
- precipitation is relatively low;
- there are no problems with leachate contamination of ground water because of site conditions or project design;
- water content of the soil-waste layer is conducive to microbiological activity.

A conservative approach is to match waste application and net soil evaporation rates. Waste application is intensive during warm and dry periods, and reduced during wet or cold periods.

Net soil evaporation is calculated by the following relationships:

$$E_N = E_S - P \qquad (2\text{-}1)$$

$$E_N = (f \times E_L) - P \qquad (2\text{-}2)$$

where:

E_N = net soil evaporation
E_S = gross soil evaporation
E_L = gross lake evaporation
P = precipitation
f = factor expressing the relationship of soil and lake evaporation (dimensionless)

Typically, gross soil evaporation in an area is estimated as a fraction (e.g. f = 0.70) of the lake evaporation. Estimates can be obtained from provincial agricultural information services.

The monthly waste application rates are calculated by matching the moisture in the applied waste to E_N, as shown in Equation (5-3):

$$RM = \frac{E_N \times TS \times C}{100 - TS} \qquad (5\text{-}3)$$

where:

R_M = monthly waste application rate (dry t/ha/mo) or (dry T/ac/mo).

E_N = net soil evaporation (cm/mo) or (in/mo)

TS = total solids content of the waste (%) by weight

C = a conversion factor which equals 100 t/cm in metric units or 113.3 T/in in English units.

The use of net soil evaporation as a basis for calculating waste application rates in conservative, since it makes no allowance for moisture removal from the waste through infiltration into the soil. If infiltration is allowed, waste application rates can be calculated by the following equation:

$$RM = \frac{E_N \times I \times TS \times C}{100 - TS} \qquad (5\text{-}4)$$

where:

I = infiltration rate (cm/mo) or (in/mo), and all other terms are the same as in Equation (5-3).

2.4 Soil Properties

2.4.1 Physical Properties

The physical properties of a soil to a great extent determine its suitability for land application activity. Physically, is made up of decaying organic matter, inorganic particles, air and water. The relative proportion of each of these determines the characteristics of the soil. Among the characteristics of concern are soil texture, permeability, and available water holding capacity.

Soil texture refers to the coarseness or fineness of the individual inorganic particles contained in the soil. This physical property is one of the most important since it determines the permeability and water-holding capacity of soil. Texture of a soil is defined by the relative proportion of particles found in the sand (>0.05 mm), silt (0.05 to

0.002 mm), and clay (<0.002 mm) size fractions. Through the use of a texture triangle (Figure 2-2), a soil horizon containing a certain percentage of sand, silt, and clay is assigned a name, such as sandy loam, silt loam, silty clay, silty clay loam, etc.

Permeability is the ease with which a fluid or gas can pass through the soil. Permeability is closely associated with particle size and pore space. The proportion of organic matter in soil also effects soil permeability. As the particle sizes become smaller, the ease with which water can flow through the soil is impeded. However, the ability of a soil to retain water is dependent upon a high percentage of smaller particles, (i.e. small pore spaces).

Coarse texture and soils, those which have a high proportion of sand, are characterized as having low water-holding capacity, high permeability and aeration, and good drainage. Fine textured soils, on the other hand, are those that contain a high proporion of silt and/or clay. A high proportion of silt is detrimental since it can lead to behaviour such as soil crusting, resulting in poor drainage. Clay particles have a very small diameter, and hence a high surface area. They therefore have a high adsorptive capacity for water, ions, and gases. This high adsorptive capacity may be useful in holding ions such as heavy metals in immobile form, preventing their movement through the soil profile. Fine-textured soils have a high water-holding capacity, low permeability and aeration, and poor drainage.

Moisture retention and soil permeability and infiltration are important since they determine the rate of waste application. In theory, hazardous waste land application units can be sited upon any soil type if proper management skills are

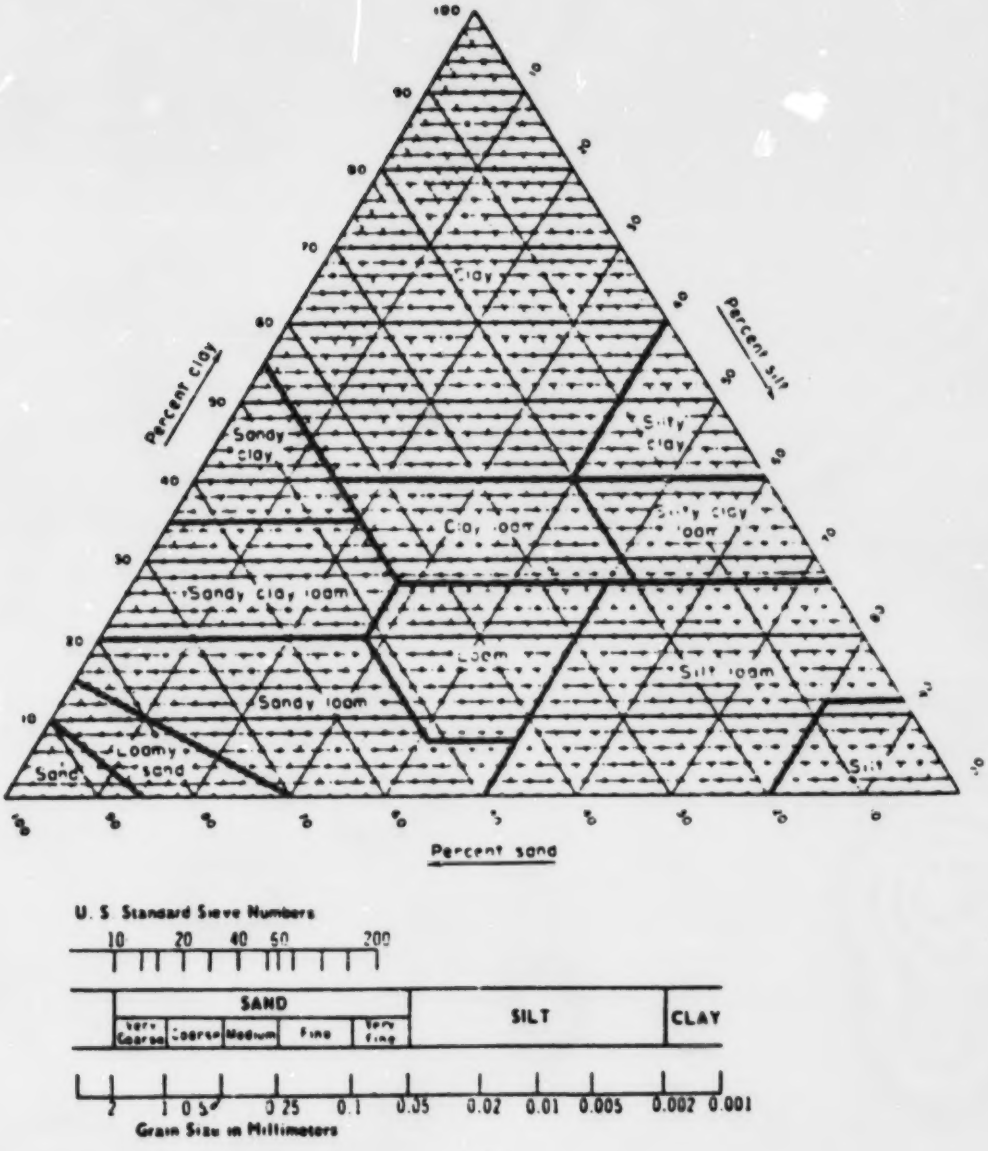

Figure 2-2. Soil textural classes and general terminology used in soil descriptions.

employed. Practically, however, treatment units should not be established on sandy soils due to the potential for waste migration into ground water and silty soils should not be considered since they are often susceptible to crusting problems that lead to excessive runoff.

2.4.2 Chemical Properties

2.4.2.1 Cation Exchange Capacity (CEC)

Clay materials are one of the more important inorganic fractions of a soil. Clay crystals are typically composed of layered sheets of tetrahedrally coordinated silicon and oxygen, and octahedrally coordinated aluminum and oxgen. Depending on the clay mineral, the sheets of silicon-oxygen tetrahedra and aluminum-oxygen octahedra are stacked either alternately, or in a sandwich configuration with two silicon-oxygen sheets to one aluminum-oxygen sheet (2:1 ratio). Kaolinite is a typical 1:1 clay mineral while montmorillonite and vermiculite are typical 2:1 clays. When trivalent aluminum or iron (+3) is substituted for tetravalent silicon (+4) and divalent magnesium or iron (+2) for trivalent aluminum (+3), a permanent net negative charge results on the surface of the clay material. This negative charge is satisfied by surface retention of a cation such as H^+, K^+, Na^+, Ca^{2+}, Mg^{2+}, Al^{13+}, etc. The magnitude of the negative charge is measured by determining the cation exchange capacity (CEC), commonly expressed in meq/100 g. The CEC arising from isomorphous substitution is not pH-dependent. However, clay minerals possess some pH-dependent CEC, arising from the dissociation of hydroxyl groups (-OH) present at the edges of broken clay crystals.

The ability of clay minerals to attract and retain cations is a very important property in soils. Other silicate minerals are less important than the clay minerals, primarily because of their minimal CEC and low surface area.

Organic matter (humus) is another important component of soils. There are two major categories of soil organic matter, humic and nonhumic substances. Nonhumic substances are intact or partially degraded compounds from plant, animal, or microbial residues. In general, nonhumic substances account for less than 25% of soil organic matter. With time these constituents decompose, and a portion of the degradation products are converted into humic substances.

Humic substances are complex, high-molecular weight organic materials that result from chemical and enzymatic reactions of organic degradation products from plant, animal, and microbial residue. Humic substances are subdivided into the following categories: fulvic acids (acid and alkali soluble), humic acids (acid insoluble, alkali soluble), and humin (acid and alkali insoluble). Although quantitative differences exist in chemical composition, all three fractions are characterized by a nonpolar (aromatic ring) core with attached polar functional groups. The nonpolar nature of humics accounts for the strong affinity of soil organic matter for added organic compounds such as herbicides, pesticides, etc. Functional groups found in soil organic matter include carboxyl (-COOH), phenolic and alcoholic hydroxyl (-OH), amino ($-NH^2$), and sulfhydryl (-SH) groups. All of these functional groups exhibit acidic or basic characteristics, and soil organic matter is thus involved in the buffering of soil pH. The ionization of the weakly acidic functional groups also results in soil organic matter possessing a net negative charge or CEC. Soil pH

strongly influences the CEC of soil organic matter with increasing pH resulting in increasing CEC. Metals may also interact with functional groups through chelation and ion exchange mechanisms.

Clay minerals and organic matter account for virtually all soil CEC. The CEC of soil organic matter normally ranges from 100 to 200 meq/100 g, whereas the CEC of clay minerals varies, depending on the mineral type, from 5 to 170 meq/100 g. Consequently, the relatively small fraction of organic matter present in a soil may exert a large influence on total CEC.

2.4.2.2 Reactions of Metals in Soil

Land application of hazardous wastes will add appreciable amounts of trace metals to soils. The chemistry of metals in soils is quite complex and difficult to predict. The fate of metals added to soils in municipal sewage sludge is depicted in Figure 2.3; the fate of metals in hazardous wastes is sparsely documented, but is thought to be similar. Metals available to plants and susceptible to leaching are present in the soil solution as the free metal ion (M^{2+}, etc.), complexes (MOH^{+}, MCl^{+}, etc.) and chelates (M-Fulvic acid, etc.).

As plant uptake or leaching occurs, the soil solution re-equilibrates with solid metal-containing phases, resulting in a relatively constant concentration in the soil solution. The equilibrium concentration will be controlled by soil

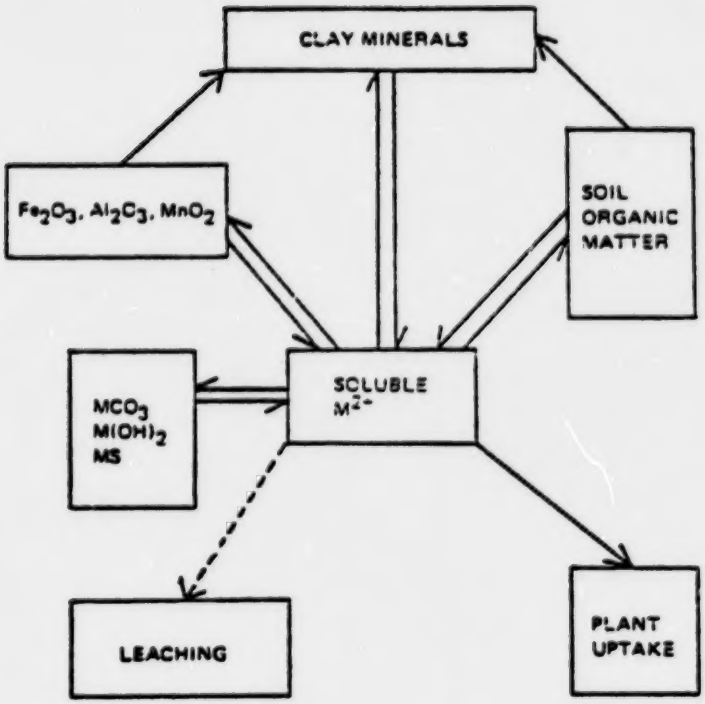

Figure 2-3. Reactions of metals in soil (M^{2+} represents Cu, Zn, Ni, Cd, Pb, etc.).

properties such as pH, Eh, and solution composition. In general, the solubility and plant availability of most metals decrease with increasing pH.

Metals in the soil solution are continuously interacting: forming precipitates (carbonates, hydroxides, phosphates, etc.), interacting with soil organic matter, being sorbed by clay minerals, and being retained by hydrous oxides. Furthermore, the properties of clay minerals in soil are influenced to a great extent by interaction with organic matter and hydrous oxides. In general, the organic matter complexed with clay is more resistant to decomposition than "free" organic matter, resulting in the clay and organic matter contents of soils increasing proportionately. The presence of acidic functional groups in soil organic matter is responsible for metal retention through both exchange and chelation mechanisms. Considerable evidence is accumulating concerning the importance of metal retention by iron and aluminum hydrous oxides. Even where hydrous oxides are sorbed onto clay minerals, they still retain the ability to sorb metals. The iron and aluminum hydrous oxide content of soils also tends to increase with increasing clay content.

The trace metal retention capacity and CEC of soils both tend to increase as the clay, hydrous oxide, and organic matter contents increase.

2.4.3 Biological Properties

The soil environment is a suitable habitat for both microscopic and macroscopic organisms. The highest population

concentration occurs at the surface, and decreases with depth due to factors such as decreased organic matter, reduced oxygen supply, increased moisture, and others.

Biological action accounts for approximately 80% of the total waste degradation in a land application site system. Five major groups of organisms are responsible for degradation: bacteria, actinomycetes, fungi, algae and protozoa. Bacteria are the most abundant. In terms of total biomass, fungi have the largest mass in soil due to their filamentous mycelial structure.

2.4.3.1 Bacteria

Soil bacteria are divided into two major groups, autotrophic and heterotropic. Autotrophic bacteria are those that derive carbon for the production of biomass from inorganic sources such as carbon dioxide or carbonates. Autotrophs derive energy for growth and respiration from sunlight (photoautotrophs) or from inorganic sources such as nitrite, ammonium, sulfur and ferrous ions (chemoautotrophs). Heterotrophic bacteria derive carbon and energy from organic compounds and may exist under aerobic or anaerobic conditions.

Soil bacteria have the ability to decompose a wide range of organic materials. Because they reproduce fairly rapidly, they govern the rate of waste degradation. Bacteria are primarily responsible for the transformations of nitrogen, sulfur and trace elements in soil.

2.4.3.2 Actinomycetes

Actinomycetes are a group of organisms which have characteristics of both bacteria and fungi. They are unicellular organisms that produce a slender branched mycelium which may undergo fragmentation or subdivide to form asexual spores. Under high pH conditions, these organisms become the most abundant in soil.

2.4.3.3 Fungi

Fungi are heterotrophic organisms which are characterized by filamentous mycelium forming a network of hyphal strands. Their existance depnds upon the availability of oxidizable carbonaceous materials. Fungi are able to exist under very adverse conditions, and function over a wide variety of soil conditions. As a result, fungi can be responsible for the decomposition of recalcitrant waste constituents.

2.4.3.4 Algae

Most algae are autotrophic organisms that derive their energy from sunlight. For autotrophic development they obtain water, nitrogen, phosphorus, sulphur, magnesium, potassium, iron, molybdenum and other trace nutrients from the soil. Algal populations cannot multiply beneath the zone of soil receiving sunlight, so most algae are found in the surface 5 cm of soil. Constant aeration of the soil promotes algal growth. Algal populations are first to colonize a barren

area, and the organic matter produced by the death of the algae provide a substrate for bacterial and fungal populations.

2.4.3.5 Other Organisms Important to Waste Degradation

Other prominent soil animals are earthworms, nematodes and protozoa. Earthworms are important in mixing the organics with the soil, thereby improving the soil structure and promoting aeration and fertility (1). Nematodes and protoza are also important in waste degradation. However, some nematodes may hinder waste degradation by feeding on bacteria, fungi, algae, protoza, and other nematodes (2).

2.4.4 Soil Environment and Activity of Microorganisms

The rate of waste decomposition depends primarily upon the chemical composition of the waste, and on those factors that affect the soil environment. Environmental factors influencing microbial growth include soil pH, air temperature, soil water content, and nutrients.

2.4.4.1 Soil pH

Most soil bacteria grow best at a pH of 7. Very few species are able to survive in conditions of very low (<4) or high (>10) pH (2). Actinomycetes are able to survive at elevated pH conditions but have a lower pH limit of about 5. Fungi survive best in neutral or alkaline soils, but are more

tolerant to low pH values than other microbes. In general, soil animals are adversely affected by acidity, especially pH below 5.

2.4.4.2 Temperature

Temperature has a profound influence on the growth and activity of microbes, and consequently will markedly affect the decomposition and biodegradation of land-applied wastes. Microbes exhibit a wide temperature tolerance range, but their optimum is usually near their upper limit (3). Most soil microorganisms are active in the temperature range between 20° to 35°C, and are categorized as mesothermic microbes. Soils also contain some microorganisms known as psychrophiles that function best below 20°C. Those that develop actively only at higher temperatures are called thermophiles, and exhibit maximal activity in the 50° to 60°C range.

As a general guideline, the activity of microbes doubles for every 10°C rise in temperature, within the microorganism's particular temperature range. Temperature also has an effect on the distribution of microbe species in the soil profile. At higher temperatures, actinomycetes predominate over fungi and bacteria. Conversely, as soil incubation temperatures decrease below 20°C, the growth of actinomycetes decreases to a greater extent than either fungi or bacteria (4).

2.4.4.3 Moisture

Microorganisms require moisture for growth and for the diffusion of nutrients and by-products during the breakdown.

process. Water requirements for different microorganisms vary considerably, therefore water availability will determine the distribution of microflora within the soil. Bacterial activity is greatest with very moist conditions, but is limited under excessively high moisture conditions due to reduction in oxygen transfer. Some fungi tend to grow and survive in soils with much lower moisture levels.

Decomposition is typically not reduced as a consequence of moisture as long as the soil moisture content is maintained between 30 and 90% of the water-holding capacity of soil. Soil organisms will, however, become essentially inactive when the soil water content drops below the plant wilting point.

2.4.4.4 Nutrients

Soil organisms require the same basic nutrient elements required by higher plants (2). Consequently, in fertile soils, inorganic nutrients seldom need to be added. However, when a waste with a high carbon-to-nitrogen (C/N) ratio (>35) is added to soil, then additional nitrogen must be added to replace the nitrogen which is consumed by microorganisms, particularly during cell protein production.

2.5 Microbial Degradation

Detoxification and degradation of a hazardous waste by soil occurs at the surface where the soil, moisture and air interact with the waste. It is particularly important that the waste be retained in the surface of the soil medium in an area known as the "treatment zone" where decomposition

occurs. In this zone, the important processes that contribute to the degradation and immobilization of the waste include microbial, chemical and photo-chemical degradation, evaporation and volatilization.

Biological processes are greatly affected once waste is applied to soil. The primary mechanism of waste degradation in soil is through biological processes. The soil flora changes to accommodate those heterotrophic microbes which can utilize the organic compounds present in the wastes, and survive under the soil conditions of pH, moisture, temperature, and nutrients.

2.5.1 Aerobic Versus Anaerobic Decomposition

Organic wastes can be biologically metabolized either aerobically or anaerobically. The end products of complete aerobic melabolism are CO_2, H_2O and biomass. In anaerobic metabolism, organic wastes are not completely decomposed, and there is an accumulation of intermediate products such as alcohols, amines, organic acids and mercaptans. Since the energy yield under anaerobic decomposition is lower, less biomass is produced per unit of organic carbon degraded. Also, while nitrate (NO_3^-) sulphate (SO_4^{2-}) are the end products of organic nitrogen and sulphur compounds under aerobic conditions, hydrogen sulphide and ammonium ion are produced under anaerobic conditions (5).

2.5.1.1 Aerobic

$(CHO)_n NS \rightarrow CO_2 + NH_4 + H_2S + Energy$

+ microbial cells and storage products (60%)

$NH_4^+ + H_2S \rightarrow NO_3^- + SO_x^{2-}$

2.5.1.2 Anaerobic

$(CHO)_n NS \rightarrow CO_2 + CH_4$ (5%) $+ H_2 + NH_4^+ + H_2S + H_2O + Energy$

+ microbial cells and storage products (20%)*

+ organic intermediates (70%)

* The percentage values are estimates of the carbon distribution of the original organic compound(s) after metabolism by the microbial population.

The formation of nitrate ion under aerobic conditions is significant, because it is soluble and may be lost through leaching and denitrification. In humid regions, nitrate can leach into the ground water, resulting in potential environmental harm. When present in an anaerobic soil it may be denitrified and lost as a gas.

2.5.2 Microbial Degradation of Specific Compounds

Recently, considerable emphasis has been placed on the study of the biodegradability of organic substances that are

considered to be potential environmental toxins (6, 7). Some of these substances are phenolic compounds, chlorinated hydrocarbon pesticides, nitrosamines, detergent residues such as alkylbenzene sulfonates (ABS) and nitrilotriacetate (NTA), and petroleum products.

2.5.2.1 Phenols

The simpler phenols (i.e. mono- or disubstituted phenols) generally undergo hydroxylation. This generally results in the formation of a catechol derivative which is the precursor to ring cleavage and dissolution of aromaticity by microorganisms. Initial biochemical activity may occur with the substituent groups; however, this initial activity depends on the biochemical activity or position of the substituent group on the aromatic ring. In addition to these reactions, phenols may undergo conjugation, methylation and condensation reactions leading to more complex molecules (8).

2.5.2.2 Pesticides

More studies have been conducted on the biodegradation of pesticides in soils than on most other compounds. The principal biochemical reactions include alkylation, dealkylation, amide or ester hydrolysis, dehalogenation, dehydrohalogenation, oxidation, reduction, dehydroxygenation, ring cleavage, ether cleavage, condensation, and conjugate formation (9).

The chemical structure, nature, and position of substituent groups affect the extent and rate of microbial degradation. This is demonstrated by the persistence of various pesticides in soils. In addition, the dosage, particle size, distribution in soil, and previous applications all influence the rate of decomposition of pesticides in the soil (10). A high application rate may be toxic to some species which would decompose the same chemical at lower concentrations. If the substance is present in layers or is not well mixed with the soil, the concentration may be too high in localized areas for growth of otherwise active organisms.

2.5.2.3 Summary

In summary, although some of the toxic organic substances do persist in soils, microbial degradation will eventually proceed if the substances are adsorbed in the soil surface for a sufficient period of time. There is, however, limited information on the environmental factors affecting degradation of these substances as well as the microorganisms and enzymatic reactions involved.

2.6 Nonbiological Degradation

Nonbiological degradation processes include photochemical degradation and chemical hydrolysis. These degradation processes have been found to play a significant role in the degradation of organic hazardous wastes.

2.6.1 Chemical Degradation

Chemical degradation of land-applied wastes is complex and poorly understood. Numerous mechanisms have been found or postulated, including oxidation, reduction, hydrolysis, isomerization, and polymerization. The degradation rate is dependent upon the pH, redox potential (Eh), and the nature, concentration and availability of catalytic sites (11). Hydrolysis reactions have been found to be important in the degradation of organic compounds, including many insecticides (12). Sorption by clay has also been found to be an important mechanism in the degradation of many compounds.

Chemical degradation by non-living enzymes is another mechanism of chemical degradation which occurs in soil. These enzymes are derived from living or dead microorganisms, root exudates and soil animals, and are extremely stable once adsorbed by buffered particulate matter (13). Extracellular enzymes have been shown by Getain and Rosefield (14), to catalyze the hydrolysis of insecticides. Other researchers have found similar catalytic and degradative properties (15, 16).

2.6.2 Photochemical Degradation

Photochemical degradation will play a minor role in land applied wastes, since only a small fraction of the treatment zone is exposed to sunlight at any one period of time. Constant discing of the surface, however, will improve soil mixing and aeration, resulting in further photochemical degradation.

2.7 Volatilization

Volatilization is a major mechanism for waste volume reduction.

Volatilization is controlled by the properties of the compound (vapor pressure, water solubility, and Henry's Law Constant), the soil (air-filled porosity and temperature), interaction between the waste and soil (application method and degree of mixing) and atmospheric conditions (wind velocity, air temperature, and relative humidity). One study found that the highest volatilization occurred within minutes of soil application, and decreased substantially within one hour (17).

Soil water content is one of the most important factors affecting volatilization. Chemicals vaporize faster from wet (but not saturated) soil than from dry soils, primarily because water increases the effective vapor pressure of the chemicals by competing for the adsorption sites (18). Increasing the waste concentration, diffusion rate, air flow rate, or air temperature will result in an increased rate of volatilization.

Volatilization is one of the major pathways of pesticide loss from field soils. Willis et.al. (19) measured atmospheric concentrations of dieldrin over field plots under three different regimes. In the plots designated for flooded treatment, 10 cm (3.9 in.) of water were applied; for moist treatment, the plot was sprinkled two to three times daily to maintain soil moisture; for nonflooded treatment, no water was applied other than natural rainfall. High atmospheric concentrations of dieldrin were found over all plots immediately after water application. It was calculated that

volatilization losses during a five month period were approximately 2% from the flood plots, 18% from the moist plots, and 7% from the nonflooded plots. In addition to the effects of soil moisture on volatilization, it was shown that air temperature influenced the volatilization rate more than any other climatic variable measured.

Compounds of most concern with regard to their potential volatilization include both those that are persistent, toxic, and/or weakly adsorbed to soil, and those that exhibit either low water solubility or high vapor pressure. Compounds that are not soluble in water tend to be available for volatilization longer because they are less likely to be removed in leachate or runoff water. Persistent organic constituents may similarly be volatilized because they tend to be present in the soil longer. Finally, the toxicity of the compound is of concern, since the more toxic an organic constituent, the larger the environmental impact per unit of material volatilized.

In a laboratory study, Farmer et al. (20) calculated that uncovered hexachlorobenzene (HCB) volatilized at 317 kg/ha/yr (283 lb/ac/yr). The corresponding volatilization losses, when the chemical was covered with 1.9 cm (0.75 in.) of soil and 1.43 cm (0.56 in.) of water were 4.56 and 0.38 kg/ha/hr (4.07 and 0.34 lb/ac/yr), respectively. When the soil water content or bulk density (through compaction) was increased, HCB flux through soil decreased, thereby reducing volatilization of the chemical.

2.8 Physical Properties

Land application of wastes results in changes in soil properties. Epstein (21) reported that incorporation of 5% (dry weight) sewage sludge into a Beltsville silt loam soil initially increased the saturated hydraulic conductivity. However, after 50 to 80 days, the hydraulic conductivity decreased to that of the original soil, due to clogging of soil pore by microbial decomposition and biomass. Water-stable aggregates averaged 28 to 35% for the sludge-amended soil, as compared to 17% for the original soil. The increase in aggregate stability should result in a more stable soil structure, since aggregates are more resistant to disintegration by water, and the disintegrated material is less apt to fill in the pore space. Epstein et al. (22) suggested that continual application of organic matter (waste) would be necessary to maintain this structure as the cementing agents are decomposed.

Industrial waste water and sludge often contain significant amounts of soluble salts. Waste waters from fruit and vegetable peeling processes contain high concentrations of sodium (23). These concentrations (with sodium adsorption ratios greater than 10) are known to deteriorate soil structure by causing swelling of the soil and subsequent reduction in permeability (24).

In summary, land cultivation of waste has been shown to result in changes in the physical properties of the soil. These changes generally lead to increased water holding capacity and improved soil structure, with exception of those wastes containing high levels of sodium. However, erosion control has been shown to decrease after waste application.

The effects of waste application on soil physical properties appear to be short-lived; large and frequent applications may be necessary to maintain these effects.

2.8.1 Chemical Properties

The application of industrial wastes to land similarly results in changes to chemical properties of the soil. Increases in soil pH, changes in soil cation capacity, and addition of toxicants to the soil have been observed. The extent of the alteration is dependent on the chemical composition, the C/N ratio, pH and Eh of the waste, and the soil type. The pH of the amended soil is a dominant factor in determining the mobility of many contaminants and plant nutrients. Several studies illustrate these effects (25, 26, 27, 28, 29).

2.8.2 Microbiological Properties

Some industrial wastes (oily waste, pulping sludge, fermentation sludge, etc.) contain large quantities of readily decomposable carbonaceous material. Additions of these wastes to soil should cause a large increase in microbiological activity.

Literature on the microbial assimilation of petroleum and its products is voluminous (30, 28, 29, 31, 32, 33). Over 100 species of bacteria, yeast, and fungi representing 31 genera have been reported to attack one or more types of petroleum hydrocarbons.

The initial effect of even low levels of oil contamination is to reduce microbial population and carbon dioxide production or C/N ratio (31, 32). Following this "shock" period (a few weeks to several months), there is generally a stimulation in microbial growth and a shift in the relative abundance of different species. The increasing number of organisms in the contaminated soil is a good indicator of a rapid breakdown of oil, which occurs if the soil is supplied with enough nitrogen and minerals such as phosphorus (32).

In the cultivation operation, the waste may not be evenly distributed through the plow depth; therefore, zones of unusually high wste concentration may exist. Some of the constituents in the waste can destroy soil microorganisms or suppress their activities, if present in excessive amounts. Parr (34) has reviewed the inhibiting effects of a large number of chemicals on microorganisms and their transformations in soil. Fungicides and fumigants, for example, function as partial soil sterilants, destroying pathogenic as well as saprophytic organisms, including those responsible for ammonification and nitrification.

2.8.3 Summary

Microbial decomposition of industrial wastes applied to land has been shown to occur. The large soil microbial population, however, may require very specific substrate, energy sources, and environmental conditions to achieve the maximum rate of waste degradation. Waste which contains high levels of certain toxic constituents (e.g. pesticides) may destroy soil microorganisms or suppress their activities.

3. CRITERIA FOR LAND APPLICATION OF WASTES

3.1 Introduction

In assessing the desirability of treating a specific waste by land application, both the technical criteria for land application and the expected quantity of the waste stream in Canada should be considered. The technical criteria are those concerning the environmental effect of land application of the wastes and the relative merits of this and other treatment methods. As well, operational requirements, such as safety, reliability, and application ease are considered. Quantities of waste available will have an impact on environmental effects to be expected, and on the operational and economic factors involved in selecting a treatment method.

3.2 Environmental and Technical Criteria for Land Application of Wastes

Land application of wastes can be divided into two types:

i) using the land for agricultural purposes where the waste acts as a nutrient or soil supplement;

ii) using the land application site solely for waste disposal.

The first type has been used extensively for municipal sewage sludges and food processing wastes (35). In this case, the limiting factors for the waste being land applied are its nutrient content and its toxicity, either to the crops or to the consumers of the crops. Properties such as toxicity, bioaccumulation factor, food chain effects, and phytotoxicity

have, in general, been considered in the setting of standards for sewage sludge land application. Limitations have been applied for properties such as the concentration of contaminants and nutrients in sludges or the quantity to be applied per hectare of land.

Most wastes classifiable as "hazardous" will exceed some of the standards for application to agricultural land. For these wastes, disposal is the sole purpose of the land application site and soil micro-organisms are used as a treatment or disposal agent rather than as an aid to crop production. In this case, waste application is not limited by effects on crops and consumers but only by the effects on the environment. It will be necessary that the land application site pose no hazard to surface or ground waters, or to neighbouring property. Preferably, constituents of the waste should not affect the soil's long-term capability to function as a degradation medium. Criteria for wastes to be treated by land application will thus include the following properties:

1. The waste must be largely degradable in soil (otherwise the disposal is basically landfilling). This means that it must have a significant content of degradable organic materials. Concentrations of phytotoxic or inhibitory materials must be low enough to cause no major difficulty in degradation.

2. Non-degradable substances must be immobilized by the soil; toxic metal contained in the waste must be capable of adsorption by the soil and not prone to removal by

leaching. This implies a relatively low level of metals in the waste and soil conditions that do not favour solubilization.

3. The waste, as applied, must not be ignitable or excessively toxic, reactive, corrosive, or pathogenic.

4. High levels of mobile or highly-toxic pollutants are unacceptable. Arsenic, lead, or mercury, for instance, will accumulate indefinitely with no reduction in their hazardous nature, so that the site will become more and more a potential environmental hazard. Refractory organic wastes will provide a similar hazard, since the waste will not degrade rapidly, and will have the potential for accumulation, leaching, and volatilization. All of these are environmentally unacceptable.

5. Both short and long-term hazards must be considered. Wastes that degrade readily, but pose some other major hazard such as carcinogenicity, will need to be considered carefully before a decision is made to dispose of them by land application. Short-term hazards are likely to affect the site operators directly as a result of continued exposure to the raw waste.

6. The waste must be capable of uniform application using conventional equipment. Wastes which can be distributed by pumping or spraying will be the most desirable.

7. Vapour pressure and odour levels must be acceptably low to avoid air pollution problems. This criterion will also apply when the waste itself is not odourous or volatile, but its degradation products are.

3.3 Other Considerations

In some cases, wastes that may be successfully applied to land can be disposed of in other, more environmentally sound, ways. Recycling, incineration, or biological oxidation are some of the optional disposal methods. Land application would be considered only if the environmental results were equal or better and the cost advantage substantial.

Successful land application projects have demonstrated that the technique is most valuable in the disposal of dilute, aqueous wastes, such as sewage or waste treatment sludges. These materials are pumpable, mostly water, and are easily mixed into soil after drying for a short time. They typically contain a small proportion of active ingredient (e.g. oil). Secure landfill disposal would be expensive because of the large volume associated with such waste streams.

3.4 Quantities of Hazardous Wastes

To acquire a perspective on the importance of different waste streams that may be amenable to land application, inventories of hazardous waste were consulted. Such inventories of hazardous wastes have been produced in Canada at both the national and provincial levels and have resulted in lists of wastes consistently considered hazardous.

To provide a comparison with other jurisdictions, several U.S. inventories were consulted; those of New York and

California were examined in some depth. This provided estimates of waste production in jurisdictions of similar population to that of Canada.

The various inventories were done using different methods, with different purposes and different definitions of hazardous waste. These factors were considered when using them to assess quantities of specific waste types in Canada. Still, an examination of these inventories shows that wastes listed as hazardous have the same sources and characteristics.

3.5 Inventory Comparison

3.5.1 Canadian Inventories

There has been considerable activity in the development of hazardous waste inventories in Canada. These inventories have varied both in scope and in method, however, so that direct comparison of their waste estimates is misleading. Inventory results across Canada are given in Appendices 1 to 7 (36, 37, 38, 39, 40, 41, 42). For consistency, where possible, wastes have been described in terms of the University of California, Davis (UCD) classification (see Appendix 10).

A summary of the results is given in Appendix 12.

The "National Inventory of Hazardous Wastes" (Appendix 8) (43) has provided total annual waste quantity estimates for Canada by Region. These are summarized as follows:

Atlantic	174,867 tonnes/year
Quebec	952,000 tonnes/year
Ontario	1,605,100 tonnes/year
Northern and Western	549,000 tonnes/year
TOTAL	3,280,967 tonnes/year

Regional Inventories provide these totals (See Appendices 1-12).

Atlantic	
Nfld.	7,223
N.B.	1,013
Quebec	N/A
Ontario	1,490,000
Northwest	246,400

Comparing the "National Inventory" and regional inventories, overall waste quantities may be estimated as follows.

Quantities shown for the Atlantic region are much higher in the "National Inventory" than those found in provincial inventories. For the North and West, "National" values are about double those of the Reid-Crowther study. (This possibly reflects a waste-generated perspective as compared to a waste-needing-disposal approach). There is reasonably close correspondence for Ontario totals. Since the Ontario inventory includes all <u>generated</u> waste, and <u>available</u> waste is considered to be significantly less, about 500,000 tonnes, (37) the National Inventory values are significantly higher than actual quantities expected for Ontario as well. Presumably the same relationship between the National Inventory's estimate for Quebec and the amount of waste available for disposal in that Province, would also apply.

If this assumption is made, Canada's total annual waste quantity requiring disposal would be expected to be in the order of 1×10^6 to 1.5×10^6 tonnes.

The waste is predominantly characterized as:

- metal bearing aqueous solutions
- oily and oil containing wastes
- solvents
- sludges

and small amounts of more specifically identified wastes. Some of these include:

- pesticide waste
- paint sludge
- ink sludge
- "tank bottom sediments"
- polymeric wastes
- photochemical wastes

Other wastes are probably included in broader categories. For example, tannery wastes may be included with "organic residues" in some inventories; wood preserving wastes with "pesticides"; and plating sludge with "heavy metal sludges". To aid in sub-categorizing these wastes, inventories developed in the United States were also consulted.

3.5.2 U.S. Inventories

Since the aggregating nature of Canadian inventories does not permit consistent detailed examination of many industrial

wastes, it is useful to look at inventories which have been broken down further. Two examples are the California and New York inventories (Appendix 9, 10 and 11) (44, 45, 46). These are of interest since the urban population of these states is similar to that of Canada. They may thus indicate a range of industrial performance within which Canada might be expected to fall. In addition, their inventories of waste are similar in total quantities to that estimated from provincial inventories. Distributions of waste are shown in Appendix 12 for comparison with Canadian figures.

3.5.2.1 California Inventory: Hauled Waste

This inventory (Appendix 9) has been compiled from waste haulers manifests.

3.5.2.2 California: Generator-based Inventory

The "generator-based" inventory (Appendix 10) shows a much greater quantity than the "hauled waste" inventory. Much of the difference is due to inclusion of aqueous wastes which are legally sewered.

Both California inventories indicate significant quantities of land application candidates - pesticides, tannery wastes, detergents, oils, and sludges with organic residues.

3.5.2.3 New York State Generator-based Inventory

The level of detail presented permits identifying some process waste streams existing in significant quantities.

For example, dye, ink, oil, paint, paper, and phenolic sludges and oil, pesticide, pharmaceutical, tannery, textile and fermentation waste are identifiable land application candidates (Appendix 11).

3.6 Wastes of Class 9.3, Transport of Dangerous Goods Regulations

The Transport of Dangerous Goods Regulation is not an inventory, but lists hazardous wastes (47). These wastes are recognized as hazardous in both Canada and the U.S.A. by several regulatory bodies. As such, disposal methods for them are scrutinized most highly. The wastes have been listed on the basis of some specific constituent or property (48). The schedule of wastes and the basis for listing are shown in Appendices 13 and 14.

While the wastes are listed as hazardous on the basis of toxicity, ignitability, reactivity, and corrosivity, it can be seen that the restrictions discussed in Section 3.2 also apply to many of them.

Most waste streams in this class contain:

a) high concentrations of heavy metals;
b) volatile or toxic organics; or
c) acutely toxic materials (such as cyanides).

These characteristics tend to disqualify wastes from land application because of high toxicity to soil organisms, or vapours hazardous to either the public or the on-site work force.

Some wastes, particularly organic and halo-organic wastes, may be used as a fuel supplement or processed to recover chemical values. A practical impediment to land application may be the form of the waste - tars or viscous liquids being difficult to apply compared to pumpable liquids or sludges.

The screening process for land application suitability may be illustrated by considering Class 9.3 wastes in the context of these land application criteria. One approach to such an exercise is shown in the Table 3-1. In this table, the eligibility of a waste stream for land application is considered in the light of an environmental hazard or hazards that would tend to disqualify it.

Considering these factors, candidate wastes from Class 9.3 include:

NA9316	Wood preserving waste sludges
NA9359-69	Certain pesticide wastes
NA9374-78	Petroleum wastes
NA9393	Ink formulation wastes
NA9399	Coking wastes - decanter tank tar sludge

There is considerable documentation and experience in the land treatment of the first three categories. For the latter two, less information is available.

Ink wastes are likely to be produced by many small generators, rather than an individual large one (49). This makes centralized disposal impractical. Considering composition, for treatment purposes they may be grouped with paint manufacturing wastes.

TABLE 3.1
CRITERIA FOR REJECTION OF LAND APPLICATION AS A WASTE TREATMENT METHOD: AS APPLIED TO WASTE TYPES 1 TO 97 OF THE TRANSPORTATION OF DANGEROUS GOODS REGULATIONS

WASTE TYPE	PRODUCT I.D. NO.	CANDIDATE FOR LAND APPL.	HEAVY METALS	PCB, DIOXIN	REACTIVE OR FLAMMABLE	TOXIC (VAPOUR)	INORGANIC	CORROSIVE	LEACHABLE	RECOVERABLE	COMMENTS
WASTE TYPE 1 (the following spent halogenated solvents used in degreasing: tetrachloroethylene, trichloroethylene, methylene chloride, 1,1,1-trichloroethane, carbon tetrachloride, and chlorinated fluorocarbons; and sludges from the recovery of these solvents in degreasing operations)	NA9301		X			X					
WASTE TYPE 2 (the following spent halogenated solvents: tetrachloroethylene, methylene chloride, trichloroethylene, 1,1,1-trichloroethane, chlorobenzene, 1,1,2-trichloro-1,2,2-trifluoroethane, ortho-dichlorobenzene, and trichlorofluoromethane, and the still bottoms from the recovery of these solvents)	NA9302					X					
WASTE TYPE 3 (the following spent non-halogenated solvents: xylene, acetone, ethyl acetate, ethyl benzene, ethyl ether, methyl isobutyl ketone, n-butyl alcohol, cyclohexanone; and methanol; and the still bottoms from the recovery of these solvents)	NA9303				X	X					
WASTE TYPE 4 (the following spent non-halogenated solvents: cresols and cresylic acid, nitrobenzene; and the still bottoms from the recovery of these solvents)	NA9304				X	X					
WASTE TYPE 5 (the following spent non-halogenated solvents: toluene, methyl ethyl ketone, carbon disulphide, isobutanol, and pyridine; and the still bottoms from the recovery of these solvents)	NA9305				X	X					
WASTE TYPE 6 (waste water treatment sludges from electroplating operations except for the following processes: (1) sulphuric acid anodizing of aluminum, (2) tin plating on carbon steel; (3) zinc plating on carbon steel; (4) aluminum or aluminum-zinc plating on carbon steel; (5) cleaning/stripping associated with tin, zinc, and aluminum plating on carbon steel; and (6) chemical etching and milling of aluminum)	NA9306		X				X				
WASTE TYPE 7 (waste water treatment sludges from the chemical conversion coating of aluminum)	NA9307						X				
WASTE TYPE 8 (spent cyanide plating bath solutions from electroplating operations except for precious metals electroplating spent cyanide plating bath solutions)	NA9308		X			X	X	X	X		
WASTE TYPE 9 (plating bath sludges from the bottom of plating baths from electroplating operations where cyanides are used in the process (except for precious metals electroplating bath sludges)	NA9309		X			X	X				

CRITERIA FOR REJECTION OF LAND APPLICATION AS A WASTE TREATMENT METHOD: AS APPLIED TO WASTE TYPES 1 TO 97 OF THE TRANSPORTATION OF DANGEROUS GOODS REGULATIONS

WASTE TYPE	PRODUCT I.D. NO.	CANDIDATE FOR LAND APPL.	HEAVY METALS	PCB, DIOXIN	REACTIVE OR FLAMMABLE	TOXIC (VAPOUR)	INORGANIC	CORROSIVE	LEACHABLE	RECOVERABLE	COMMENT
WASTE TYPE 10 (spent stripping and cleaning bath solutions from electroplating operations where cyanides are used in the process (except for precious metals electroplating spent stripping and cleaning bath solutions)	NA9310		X			X	X				
WASTE TYPE 11 (quenching bath sludge from oil baths from metal heat treating operations where cyanides are used in the process (except for precious metals heat treating quenching bath sludges)	NA9311		X			X	X				
WASTE TYPE 12 (spent cyanide solutions from salt bath pot cleaning from metal heat treating operations (except for precious metals heat treating spent cyanide solutions))	NA9312					X	X				
WASTE TYPE 13 (quenching waste water treatment sludges from metal heat treating operations where cyanides are used in the process (except for precious metals heat and treating quenching waste water treatment sludges)	NA9313					X	X				
WASTE TYPE 14 (cyanidation waste water treatment tailing pond sediment from mineral metals recovery operations)	NA9314					X	X				
WASTE TYPE 15 (spent cyanide bath solutions from mineral metals recovery operations)	NA9315					X	X				
WASTE TYPE 16 (bottom sediment sludge from the treatment of waste waters from wood preserving processes that use creosote and/or pentachlorophenol)	NA9316	X									
WASTE TYPE 17 (waste water treatment sludge from the production of chrome yellow and orange pigments)	NA9317		X								
WASTE TYPE 18 (waste water treatment sludge from the production of molybdate orange pigments)	NA9318		X								
WASTE TYPE 19 (waste water treatment sludge from the production of zinc yellow pigments)	NA9319		X								
WASTE TYPE 20 (waste water treatment sludge from the production of chrome green pigments)	NA9320		X								
WASTE TYPE 21 (waste water treatment sludge from the production of chrome oxide green pigments (anhydrous and hydrated)	NA9321		X								
WASTE TYPE 22 (waste water treatment sludge from the production of iron blue pigments)	NA9322		X								
WASTE TYPE 23 (oven residue from the production of chrome oxide green pigments)	NA9323		X								
WASTE TYPE 24 (distillation bottoms from the production of acetaldehyde from ethylene)	NA9324					X		X			

CRITERIA FOR REJECTION OF LAND APPLICATION AS A WASTE TREATMENT METHOD: AS APPLIED TO WASTE TYPES 1 TO 97 OF THE TRANSPORTATION OF DANGEROUS GOODS REGULATIONS

WASTE TYPE	PRODUCT I.D. NO.	CANDIDATE FOR LAND APPL.	HEAVY METALS	PCB, DIOXIN	FLAMMABLE	TOXIC (VAPOUR)	INORGANIC	CORROSIVE	LEACHABLE	RECOVERABLE	COMMENTS
WASTE TYPE 25 (distillation side cuts from the production of acetaldehyde from ethylene)	NA9325				X	X					
WASTE TYPE 26 (bottom stream from the waste water stripper in the production of acrylonitrile)	NA9326					X					HCN
WASTE TYPE 27 (bottom stream from the acetonitrile column in the production of acrylonitrile)	NA9327					X					HCN
WASTE TYPE 28 (bottoms from the acetonitrile purification column in the production of acrylonitrile)	NA9328					X					
WASTE TYPE 29 (still bottoms from the distillation of benzyl chloride)	NA9329				X	X					
WASTE TYPE 30 (heavy ends or distillation residues from the production of carbon tetrachloride)	NA9330					X					
WASTE TYPE 31 (heavy ends from the fractionation column in ethyl choride production)	NA9331				X	X				X	
WASTE TYPE 32 (heavy ends from the distillation of ethylene dichloride in ethylene dichloride production)	NA9332					X				X	
WASTE TYPE 33 (heavy ends from the distillation of ethylene dichloride in ethylene dichloride production)	NA9333				X	X				X	
WASTE TYPE 34 (heavy ends from the distillation of vinyl chloride in vinyl chloride monomer production)	NA9334				X	X				X	
WASTE TYPE 35 (aqueous spent antimony catalyst waste from vinyl chloride monomer production)	NA9335		X								
WASTE TYPE 36 (distillation bottoms from the production of phenol/acetone from cumene)	NA9336	X									Hard to handle
WASTE TYPE 37 (distillation light ends from the production of phthalic anhydride from naphthalene)	NA9337					X					
WASTE TYPE 38 (distillation bottoms from the production of phthalic anhydride from naphthalene)	NA9338	X									Hard to handle
WASTE TYPE 39 (distillation light ends from the production of phthalic anhydride from orthoxylene)	NA9339					X					
WASTE TYPE 40 (distillation bottoms from the production of phthalic anhydride from orthoxylene)	NA9340	X									Hard to handle
WASTE TYPE 41 (distillation bottoms from the production of nitrobenzene by the nitration of benzene)	NA9341					X					
WASTE TYPE 42 (stripping still tails from the production of methyl ethyl pyridines)	NA9342					X					
WASTE TYPE 43 (centrifuge and distillation residues from toluene diisocyanate production)	NA9343					X					

CRITERIA FOR REJECTION OF LAND APPLICATION AS A WASTE TREATMENT METHOD: AS APPLIED TO WASTE TYPES 1 TO 97 OF THE TRANSPORTATION OF DANGEROUS GOODS REGULATIONS

WASTE TYPE	PRODUCT I.D. NO.	CANDIDATE FOR LAND APPL.	HEAVY METALS	PCB, DIOXIN	REACTIVE OR FLAMMABLE	TOXIC (VAPOUR)	INORGANIC	CORROSIVE	LEACHABLE	RECOVERABLE	COMMENTS
WASTE TYPE 44 (spent catalyst from the hydrochlorinator reactor in the production of 1,1,1-trichloroethane)	NA9344					X	X				
WASTE TYPE 45 (waste from the product stream stripper in the production of 1,1,1-trichloroethane)	NA9345					X					
WASTE TYPE 46 (distillation bottoms from the production of 1,1,1-trichloroethane)	NA9346									X	
WASTE TYPE 47 (heavy ends from the heavy ends columns from the production of 1,1,1-trichloroethane	NA9347									X	
WASTE TYPE 48 (column bottoms or heavy ends from the combined production of trichloroethylene and perchloroethylene)	NA9348									X	
WASTE TYPE 49 (distillation bottoms from aniline production)	NA9349					X					
WASTE TYPE 50 (process residues from aniline extraction from the production of aniline)	NA9350				X						
WASTE TYPE 51 (combined waste water streams generated from nitrobenzene/aniline production)	NA9351					X		X			
WASTE TYPE 52 (distillation of fractionating column bottoms from the production of chlorobenzenes)	NA9352									X	
WASTE TYPE 53 (separated aqueous stream from the reactor product washing step in the production of chlorobenzene)	NA9353					X					
WASTE TYPE 54 (by-product salts generated in the production of MSMA and cacodylic acid)	NA9354		X								
WASTE TYPE 55 (waste water treatment sludge from the production of chlordane)	NA9355										Intractable
WASTE TYPE 56 (waste water and scrub water from the chlorination of cyclopentadiene in the production of chlordane	NA9356										Intractable
WASTE TYPE 57 (filter solids from the filtration of hexachlorocyclopentadiene in the production of chlordane)	NA9357										Intractable
WASTE TYPE 58 (vacuum stripper discharge from the chlordane chlorinator in the production of chlordane)	NA9358										Intractable
WASTE TYPE 59 (waste water treatment sludges generated in the production of creosote)	NA9359	X									
WASTE TYPE 60 (still bottoms from toluene reclamation distillation in the production of disulfoton)	NA9360	?			X	X					
WASTE TYPE 61 (waste water treatment sludges from the production of disulfoton)	NA9361	?				X					
WASTE TYPE 62 (waste water from the washing and stripping of phorate production)	NA9362	?				X					
WASTE TYPE 63 (filter cake from the filtration of diethylphosphorodithioic acid in the production of phorate)	NA9363	?				X					

CRITERIA FOR REJECTION OF LAND APPLICATION AS A WASTE TREATMENT METHOD: AS APPLIED TO WASTE TYPES 1 TO 97 OF THE TRANSPORTATION OF DANGEROUS GOODS REGULATIONS

WASTE TYPE	PRODUCT I.D. NO.	CANDIDATE FOR LAND APPL.	HEAVY METALS	PCB, DIOXIN	REACTIVE OR FLAMMABLE	TOXIC (VAPOUR)	INORGANIC	CORROSIVE	LEACHABLE	RECOVERABLE	COMMENTS
WASTE TYPE 64 (waste water treatment sludge from the production of phorate)	NA9364	?				X					
WASTE TYPE 65 (waste water treatment sludge from the production of toxaphene)	NA9365					X			X		Intractable
WASTE TYPE 66 (untreated process wastewater from the production of toxaphene)	NA9366					X			X		Intractable
WASTE TYPE 67 (heavy ends or distilleton residues from the distillation of tetrachlorobenzene in the production 2,4,5-T)	NA9367					X			X		Intractable
WASTE TYPE 68 (2,6-dichlorophenol waste from the production of 2,4-D)	NA9368					X			X		Intractable
WASTE TYPE 69 (untreated waste water from the production of 2,4-D)	NA9369					X					
WASTE TYPE 70 (waste water treatment sludges from the manufacturing and processing of explosives)	NA9670		X		X						
WASTE TYPE 71 (spent carbon from the treatment of waste water containing explosives)	NA9671				X						
WASTE TYPE 72 (waste water treatment sludges from the manufacturing, formulation, and loading of lead-based initiating compounds)	NA9672		X		X						
WASTE TYPE 73 (pink/red water from TNT operations)	NA9373				X						
WASTE TYPE 74 (dissolved air flotation (DAF) float from the petroleum refining industry)	NA9374	X	X								
WASTE TYPE 75 (slop oil emulsion solids from the petroleum refining industry)	NA9375	X	X								
WASTE TYPE 76 (heat exchanger proposed bundle cleaning sludge from the petroleum refining industry)	NA9376	X	X								
WASTE TYPE 77 (API separator sludge proposed from the petroleum refining industry)	NA9377	X	X								
WASTE TYPE 78 (tanks bottoms (leaded) from the petroleum refining industry)	NA9378	X	X								
WASTE TYPE 79 (ammonia still lime sludge from coking operations)	NA9379		X				X				
WASTE TYPE 80 (emission control dust/sludge from the primary production of steel in electric furnaces)	NA9380		X			X					
WASTE TYPE 81 (spent pickle liquor from steel finishing operations)	NA9381		X				X				
WASTE TYPE 82 (sludge from lime treatment of spent pickle liquor from steel finishing operations)	NA9382		X				X				
WASTE TYPE 83 (acid plant blowdown slurry/sludge resulting from the thickening of blowdown slurry from primary copper production)	NA9383		X				X				

CRITERIA FOR REJECTION OF LAND APPLICATION AS A WASTE TREATMENT METHOD: AS APPLIED TO WASTE TYPES 1 TO 97 OF THE TRANSPORTATION OF DANGEROUS GOODS REGULATIONS

WASTE TYPE	PRODUCT I.D. NO.	CANDIDATE FOR LAND APPL.	HEAVY METALS	PCB, DIOXIN	REACTIVE OR FLAMMABLE	TOXIC (VAPOUR)	INORGANIC	CORROSIVE	LEACHABLE	RECOVERABLE	COMMENTS
WASTE TYPE 84 (surface impoundment solids contained in and dredged from surface impoundments at primary lead smelting facilities)	NA9384		X				X				
WASTE TYPE 85 (sludge from treatment of process waste water and/or acid plant blowdown from primary zinc production)	NA9385		X				X				
WASTE TYPE 86 (electrolytic anode slimes/sludges from primary zinc production)	NA9386		X				X				
WASTE TYPE 87 (cadmium plant leach residue (iron oxide) from primary zinc production)	NA9387		X				X				
WASTE TYPE 88 (emission control dust/sludge from secondary lead smelting)	NA9388		X				X				
WASTE TYPE 89 (waste leaching solution from acid leaching of emission control dust/sludge from secondary lead smelting)	NA9389		X				X				
WASTE TYPE 90 (brine purification muds from the mercury cell process in chlorine production where separately prepurified brine is not used)	NA9390		X				X				
WASTE TYPE 91 (chlorinated hydrocarbon wastes from the purification step of the diaphragm cell process using graphic anodes in chlorine production)	NA9391		X				X				
WASTE TYPE 92 (waste water treatment sludge from the mercury cell process in chlorine production)	NA9392		X								
WASTE TYPE 93 (solvent washes and sludges, caustic washes and sludges, or water washes and sludges from cleaning tubs and equipment used in the formulation of ink from pigments, driers, soaps and stabilizers containing chromium and lead	NA9393	X	X								
WASTE TYPE 94 (waste water treatment sludges generated during the production of veterinary pharmaceuticals from arsenic or organo-arsenic compounds)	NA9394		X								
WASTE TYPE 95 (distillation tar residues from the distillation of aniline-based compounds in the production of veterinary pharmaceuticals from arsenic or organo-arsenic compounds)	NA9395		X			X					
WASTE TYPE 96 (residue from the use of activated carbon for decolourization in the production of veterinary pharmaceuticals from arsenic or organo-arsenic compounds).	NA9396		X								
WASTE TYPE 97 (decanter tank tar sludge from coking operations)	NA9397	X				X					

Coke oven decanter tank tar sludge can be recycled to the coking process, a highly acceptable disposal route.

3.7 Wastes Available

The screening criteria for land application of wastes eliminate many of the wastes to be expected in Canada from consideration. If the wastes in Appendix 12 are considered, the "00" prefix classes pose too high an immediate handling hazard; the 100 series would not be assimilated or destroyed in soil, and would pose the same hazards to the environment as they do in uncontrolled landfills; and most solvents have unacceptably high vapour pressure.

Some wastes are, however, expected in significant quantities, and might be disposed of environmentally soundly by land application. Candidates for consideration include some pesticide wastes, tannery wastes, adhesive wastes, polymer wastes, oily wastes, ink sludge, metal-containing sludges, paint sludges and sludges with organic residues.

Generally, these wastes have a high water content or a high content of degradable organic matter, and a relatively low content of undegradable contaminants such as metals, arsenic, fluoride, etc., which must be bound by soil minerals. In addition, they cover a wide enough range of industrial activity that practices applicable to them may be relevant to other industries' waste streams.

4. LEGISLATION AND GUIDELINES

4.1 Introduction

Legislation on the disposal of wastes will control both the availability of sites for land application of wastes and the specific practices that may be followed. However, since land application is not a widespread practice, legislation specific to it often does not exist, and in these cases land application falls under omnibus pollution control or waste disposal regulations. Where the process is not specifically recognized, interpretation of the legislation may be necessary to determine its applicability or the policy of the regulatory body to land application.

The review of the legislation will focus on those aspects which are specific to land application, where such exist, and otherwise on more general provisions or enabling legislation whose principles may affect land application practice.

Generally, formal guidelines for land application of wastes have been designed for agricultural purposes. As such, they are included here as an illustration of the principles followed in setting standards, both in Canada and elsewhere. It is not intended that they be construed as being legal requirements or even directly applicable to land application for treatment or disposal purposes only.

4.2 Legislation

Canada

These are no federal regulations directly applicable to land application of wastes. The following legislation limits the impacts of land application in other environmental areas.

Fisheries Act, R.S.C. 1970, c.F14.

Section 31.(1) No person shall carry on any work or undertaking that results in the harmful alteration, disruption or destruction of fish habitat.

Section 33.(2) Subject to subsection(4), no person shall deposit or permit the deposit of a deleterious substance of any type in water frequented by fish or in any place under any conditions where such deleterious substance or any other deleterious substance that results from the deposit of such deleterious substance may enter any such water". R.S.C. 1970c. 17 (1st Supp).

Northern Inland Waters Act, R.S.C. 1970 (1st Supp.), c.28.

Section 6.(1) Except in accordance with the conditions of a licence or as authorized by the regulations, no person shall deposit or permit the deposit of waste of any type in any waters or in any place under any conditions where such waste or any other waste that results from the deposit of such waste may enter any waters.

Environmental Contaminants Act R.S.C. 1974-75, c.72

Section 8.(1) No person shall, in the course of a commercial, manufacturing or processing activity, wilfully release, or permit the release, of a

substance specified in the schedule or any substance that is a member of a class of substances specified in the schedule into the environment in any geographical area prescribed in respect of that substance or class of substances or, if no geographical area is so prescribed, in Canada.

a) in a quantity or concentration that exceeds the maximum quantity or concentration prescribed in respect of that substance or class of substances for the purpose of this paragraph; or

b) under conditions prescribed in respect of such substance or class of substances for the purpose of this paragraph.

Wildlife Area Regulations

Section 3.(1) ...no person shall, in any wildlife area,

(m) dump or deposit any rubbish, waste material or substance that would degrade or alter the quality of the environment

unless he does so under an in accordance with a permit issued by the Minister pursuant to Section 4.

Northwest Territories

Environmental Protection Ordinance R.O.N.W.T. 1974, C.E-3.

Discharge of Contaminants

Section 6.(1) No person shall discharge or permit the discharge of any contaminant into the environment that:

a) causes or contributes or is likely to cause or contribute to substantial impairment of the quality of the environment; or

b) adversely affects or is likely to adversely affect the health, safety and comfort of any person.

Alberta

There are currently no regulatory requirements specifically for land application operations. Several Acts contain provisions that could apply to aspects of land application operations.

Agricultural Chemicals Act, R.S.A. 1970 c.4

Section 9. No person shall

a) dispose of any pesticide or mixture containing a pesticide, or

b) bury, decontaminate, burn or otherwise dispose of any container that has been used to hold a pesticide,

except at a site or in a manner, as the case may be, that is

c) prescribed by the regulations, or

d) in the absence of regulations, recommended by the manufacturer of the pesticide or the Minister.

Clean Water Act, R.S.A. 1980 c-13

Section 3.(1) ...no person shall commence the construction of

i) plant, structure or thing designed for use in preventing or controlling water pollution or regulating water quality, or

k) any other type of plant, structure or thing specified in the regulations as being subject to this section,

unless the Director of Standards and Approvals issues a permit thereof.

The Clear Water Act, S.A. 1971 c.17.

Section 17.1(1) Subject to subsection (2), no person shall deposit or permit the deposit of a water contaminant

a) in a watercourse

b) in surface water

c) in underground fresh water, or

d) in any place under any conditions where that water comtaminant or any other water comtaminant that results from the deposit of the water contaminant may enter any watercourse, surface water or underground fresh water,

if it degrades, alters or forms part of or is likely to degrade, alter or form part of the process of degradation or alteration of the chemical or biological quality of water, so that the water in the watercourse, surface water or underground fresh water is or is likely to be rendered harmful to human health or life, fish, wildlife, livestock or plants.

(2) Subsection (1) does not apply to the deposit of a water contaminant of type, in a quantity and under terms and conditions stated.

a) in an approval or certificate issued by the Provincial Board of Health pursuant to the Public Health Act or regulations under it,

b) in an approval issued by the Director of Pollution Control pursuant to this Act or Regulations under it,

c) in a licence issued by the Director of Standards and Approvals pursuant to this Act or regulations under it,

d) in an approval permit or licence issued by the Energy Resources Conservation Board, or

e) in a permit issued pursuant to the Agricultural Chemicals Act.

The Provincial Board of Health Regulations Respecting the Control of Refuse Disposal Systems, 1971

Section 12.3(1)...no person, municipality or corporation shall dispose of waste material in any place other than:

a) a dry disposal site, modified landfill, sanitary landfill or unclassified waste disposal system established, operated and maintained in accordance with these regulations, or

b) an incinerator constructed, operated and maintained in accordance with:

i) the Provincial Board of Health Regulations for the Control of Air Pollution, and

ii) the Clean Air Act and Regulations made pursuant thereto.

The Soil Conservation Act, R.S.A. 1970, c.348

Section 4 Every person who owns, occupies or controls land:

a) shall take active measures to prevent soil deterioration upon the land by the action of wind or water or by any other cause, and;

b) shall obey any notice given pursuant to this Act.

Applicable guidelines for disposal practices are given in Section 5.3.

British Columbia

Pollution Control Act, S.B.C. 1967, c.34.

Section 5(1) Subject to subsection(1a), after the first day of January 1970, no person shall, directly or indirectly, discharge or cause or permit the discharge of effluent or other waste material on, in, or under any land or into any water without a permit or approval from the Director.

Waste Management Act, S.B.C. 1982

Waste Disposal Strict Liability 3(1)
Subject to subsection (3), no person shall introduce or cause or allow to be introduced into the environment waste produced by the conduct of

a) an industry, trade or business, or

b) any prescribed activity or operation carried on by any prescribed class of persons,

and, for the purpose of this subsection, a municipality that stores, treats, handles, transports, discharges or otherwise dispose of waste, is deemed to conduct an industry, trade or business.

(2) Subject to subsection (3), no person shall introduce waste into the environment in such a manner or quantity as to cause pollution.

(3) Nothing in this section or in a regulation made for the purpose of subsection (1) (b) prohibits

a) the disposition of waste in compliance with a permit, approval, order or the regulations, or with a waste management plan approved by the minister, ...

Lands application is currently considered as the discharge of refuse and a permit is required under this Act.

Manitoba

Clean Environment Act, S.M. 1972, c.76.

Section 4 — No person, either directly or indirectly, shall cause, suffer, or permit the contamination of soil in excess of prescribed limits.

Section 14(1) — No person shall, unless exempted under Section 14.1 or by the regulations, construct premises or alter same or set into operation any industry, undertaking, plant or process that will or may result in the discharge or emission of any contaminant into the environment, unless he files his proposal with the department or a form approved by the minister; and upon the filing of the proposal the minister

a) may approve the proposal, provided the proposal complies with the provisions of the Act and Regulations; or

b) subject to Clause(a) shall refer the proposal to the commission to be dealt with in accordance with subsection (2) or (3).

Although no reference is made to land application of wastes, similar approval procedures as are required for landfill operations appear applicable.

Operating and site conditions are specified for landfills in the Waste Disposal Grounds Regulation of 1976.

New Brunswick

No legislation applies specifically to land application of wastes.

Clean Environment Act, R.S.N.B. 1973, c.C-6.

Section 5(1) The Minister may issue a control order requiring the person to whom it is directed to do one or more of the following, namely:

a) to limit or control the rate of discharging, emitting, leaving, depositing or throwing of any contaminant or waste into or upon the environment, or any part thereof, in accordance with the directions set out in the order;

b) to stop the discharging, emitting, leaving, depositing or throwing of any contaminant or waste into or upon the environment, or any part thereof.

Water Quality Regulation 76-154.

Section 3.(2) No person shall, without an approval, cause or permit a source to emit, discharge, deposit, leave or throw any contaminant into or upon the environment in any location such that it may, directly or indirectly, cause water pollution to any waters of the Province.

New Brunswick has a Guideline for land disposal of solid wastes which includes site-specific, operation, and maintenance requirements. Some of these may be applicable to land application of wastes.

Newfoundland

This act may be construed as applying to any disposal operation.

The Waste Material (Disposal) Act, 1973. S. NFLD. 1973, c.82. Regulation 32/74

Section 17.(1) Every applicant for a certificate to establish, alter, enlarge or extend a waste management system or a waste disposal site shall submit to the Deputy Minister an application for such certificate in the form, if any, prescribed in the regulations together with

a) plans and specifications of the work to be undertaken

b) proof of compliance with Subsection (2) of this section; and

c) such other information as the Deputy Minister may prescribe

Nova Scotia

Environmental Protection Act, S.N.S. 1973, c.6.

Section 23.(1) No person shall own, occupy, operate or be responsible for the operation of a plant,

structure, facility, undertaking or thing that discharges, releases, deposits, drains, emits or threatens or allows the discharge, release, deposit or drainage or emission of waste into the environment or otherwise causes or tends to cause pollution unless he has obtained a permit from the Minister.

A permit for a land application operation would be required under this Act. Guidelines for landfills are in existence, but none specifically for land application sites.

Ontario

The Environmental Protection Act, S.O. 1971, c.86.

Section 5.(1) No person shall deposit in, add to, emit or discharge into the natural environment any contaminant, and no person responsible for a source of contaminant shall permit the addition to, emission or discharge into the natural environment of any contaminant from the source of contaminant, in an amount, concentration or level in excess of that prescribed by the regulations.

Section 31. No person shall use, operate, establish, alter, enlarge or extend,

a) a waste management system; or

b) a waste disposal site, unless a certificate of approval or provisional certificate of approval therefore has been issued by the Director and except in accordance with any conditions set out in such certificate.

Although not specific to land application sites, provisional certificates of approval have been required for petroleum waste land application. Guidelines for land application of sewage sludge are discussed in Section 5.3.

Prince Edward Island

Environmental Protection Act, S.P.E.I. 1975, c.9.

Section 9.(1) Unless approved by the Minister, no person shall discharge or deposit any material of any kind onto land or into the air or into any well, lake, river, pond, stream, spring, reservoir, or other water or watercourse or on any shore or bank thereof, or into any place that may cause pollution or impair the quality of the land, air or water.

Quebec

Environmental Quality Act, S.Q. 1972, c.49.

Division IV - Protection of the Environment

Section 20. No one may emit, deposit, issue or discharge or allow the emission, issuance or discharge into the environment of a contaminant in a greater quantity or concentration than that provided for by the regulation of the Lieutenant Governor in Council.

Land application of wastes requires a permit under this Act; conditions for the permit are site-specific.

Saskatchewan

Water Resources Management Act, R.S.S. 1978, c.W-7

Section 27. ...no person shall discharge, deposit, drain or release any substance capable of changing the quality of water or causing water pollution.

Pest Control Products (Saskatchewan) Act R.S.S. 1973, c.72

Section 8. No person shall:

a) dispose of any pesticides or mixture containing a pesticide; or

b) bury, decontaminate, burn or otherwise dispose of any container that has been used to hold a pesticide;

except at a site prescribed in the regulations and in a manner except at a site prescribed in the regulations and in a manner prescribed in the regulations or, in the absence of regulations, in a manner recommended by the manufacturer.

Pollution Prevention Regulations for the Mineral Industry

Section 13. No industrial waste shall be released to the environment of the mine or plant unless proper provisions have been made by the owner for the prevention and control of pollution resulting from the operation of his mine or plant.

Waste Management Regulations

Section 30. Petroleum wastes, slaughter house wastes and other comparable wastes shall not be deposited at a dry disposal site or in a cell within a waste disposal ground, but shall be disposed of in the manner prescribed from time to time by the Minister and approved by the Minister of the Environment.

Land application permit applications would be reviewed by the departments of Health and Environment and site-specific conditions set for the operation.

Summary

Much of Canada's environmental and waste control legislation is directed at the prevention of water pollution. As a consequence, the potential of land application operations to generate runoff or leachate becomes a major consideration. In siting a land application operation, eliminating the possibility of contamination of waters becomes a high priority.

Other legislation addresses contamination of soil from the perspective of indiscriminate dumping. The controlled use of soil as a degradation medium is not considered. Establishment of a land application operation in these cases would require both interpretation of the legislation in the land application context, and determination of the jurisdiction's policy regarding preferences in disposal methods.

4.3 Guidelines for Land Application Operations: Contaminant Levels

In general, these are guides for the use of wastes on arable land, for the protection of food crops. They will, however, serve to illustrate the soil contamination levels currently considered acceptable for food production or as a lower limit for phytotoxic effects. Canadian and foreign guidelines are considered, both for legal implications and technical considerations.

4.3.1 Canada

4.3.1.1 Ontario

ACCEPTABLE METAL CONCENTRATIONS IN DRIED AND COMPOSTED SEWAGE SLUDGE (50)

Metal	Maximum Acceptable Metal Addition (kg/ha)	Maximum Acceptable Metal Concentration In Sludges and Composts Containing 5% of Total Nitrogen or less (mg/l)
Arsenic	14	70
Cadmium	1.6	10
Cobalt	30	150
Chromium	210	1000
Copper	150	750
Mercury	0.8	4
Molybdenum	4.0	20
Nickel	32	160
Lead	90	450
Selenium	2.4	12
Zinc	330	1650

These guidelines are for protection of food crop and long-term usability of the land. Essentially, the metal content of the sludge is considered to be available for crop uptake.

4.3.1.2 Alberta: Maximum Cumulative Additions of Sludge-Borne Elements to Soils* (kg/ha) (51)

	B**	Cd	Cr	Cu	Hg	Ni	Pb	Zn
Class 1 Sites	10	1.5	100	200	0.5	25	100	300
Class 2 Sites	7.5	1.1	75	150	0.4	19	75	200
Class 3 Sites	5	0.8	50	100	0.2	12	50	150

* Not more than one-third of the cummulative loading may be applied in a single application.

** Boron levels are hot-water soluble. Levels for other elements are based on total quantities.

4.3.1.3 Alberta: Guidelines for the Disposal of Sulphur Containing Solid Wastes (52)

The method consists of applying the sulphur contaminated solid waste evenly across an area of land at a maximum rate of 2 tonnes of sulphur/acre. Either prior to or immediately following an application of the waste to a disposal area, the calculated amount of $CaCO_3$ (ground limestone) or $Ca(OH)_2$ (hydrated lime) should be spread evenly over the area of disposal to achieve pH control.

Using suitable tillage equipment, the waste and lime or limestone must be incorporated into the soil immediately after spreading.

When a small amount of sulphur-contaminated solid waste is generated periodically, the same area may be used for disposal a number of times before reaching a maximum 2 tonnes of sulphur/acre.

The disposal area should be used in a three or four year cycle; disposing of up to 2 tonnes of sulphur/acre on a given area every third or fourth year. During the years between disposal, the area should be either sown to a grass mixture or farmed in some way (should support vegetation). A regular soil sampling program should then be followed to ensure pH control.

Disposal via this method is not recommended during the winter as the potential for surface water contamination is significant since incorporation into the soil is not possible.

4.3.1.4 Pictou County, Nova Scotia

SUGGESTED METAL CRITERIA FOR AGRICULTURAL APPLICATION OF SEWAGE SLUDGE IN PICTOU COUNTY, NOVA SCOTIA (53)

Column Metal	Pictou County Soil Average	Suggested Maximum Content	Pictou County Suggested Max. Addition	
Unit	ppm	ppm	ppm	kg/ha
Arsenic	9.35	28.0	18.7	42
Cadmium	1.10	4.5	3.4	8
Cobalt	25.31	50.0	24.7	55
Chromium	63.39	112.0	48.6	109
Copper	28.33	111.0	82.7	185
Lead	29.62	445.0	415.4	930
Mercury	0.05	0.5	0.45	1
Molybdenum	1.51	3.0	1.5	3.5
Nickel	26.54	44.5	18	40
Zinc	111.18	223.0	111.8	251

Soil pH should be brought to 6.5 or more before application. The criteria are set based on plant toxicity and metal uptake.

4.3.2 United States

Recommended Cumulative Limits (kg/ha) for Metals of Major Concern applied to Agricultural Cropland. (54)

Metal	Soil Cation Exchange Capacity meq/100 g <5	5-15	>15
Lead	560	1120	2240
Zinc	280	560	1120
Copper	140	280	560
Nickel	140	280	560
Cadmium	5	10	20

Other elements are not included in the design criteria because of either minimal potential for crop uptake or low concentrations expected in (municipal) sludges.

SUMMARY OF JOINT EPA/FDA/USDA GUIDELINES FOR SLUDGE APPLICATION FOR FRUITS AND VEGETABLES PRODUCTION (55)

Annual and Cumulative Cd Rates

Annual rate should not exceed 0.5 kg/ha. Cumulative Cd loadings should not exceed 5, 10, or 20 kg/ha, depending on soil pH and Cation Exchange Capacity (CEC) values of <5, 5 to 15, and >15 meq/100 g, respectively.

Soil pH

Soil pH (plow zone - top 6 in.) should be 6.5 or greater at time of each sludge application.

PCB's

Sludges with PCB concentrations greater than 10 mg/kg should not be incorporated into the soil.

Pathogen Reduction

Sludge should be treated by pathogen reduction process before soil application. Waiting period of 12 to 18 months before a crop is grown may be required, depending on prior sludge processing and disinfection.

Use of High-Quality Sludge

High-quality sludge should not contain more than 25 mg/kg Cd, 1,000 mg/kg Pb, and 10 mg/kg PCB (dry weight basis).

Cumulative Lead Application Rate

Cumulative Pb loading should not exceed 800 kg/ha.

Pathogenic Organisms

A minimum requirement is that crops to be eaten raw should not be planted in sludge-amended fields within 12 to 18 months after the last sludge application. Further assurance of safe and wholesome food products can be achieved by increasing the time interval to 36 months.

Physical Contamination and Filth

Sludge should be applied directly to soil and not directly to any human food crop. Crops grown for human consumption on sludge-amended fields should be processed with good food industry practices, especially for root crops and low-growing fresh fruits and vegetables.

Soil Monitoring

Soil monitoring should be performed on a regular basis, at least annually for pH. Every few years, soil tests should be run for Cd and Pb.

Choice of Crop Type

The growing of plants which do not accumulate heavy metals is encouraged.

4.3.3 Federal Republic of Germany

NOXIOUS COMPONENTS IN SLUDGE GUIDE (56)
MG/KG IN SLUDGE (DRY BASIS)

	Upper Limit	Target
Zinc	3,000	2,000
Copper	1,200	600
Nickel	200	100
Cadmium	30	10
Lead	1,200	600
Chromium	1,200	600
Mercury	25	10

4.3.4 Summary

These limits do not, except for the "Recommended Cumulative Limits (kg/ha) for Metals of Major Concern applied to Agricultural Cropland", address soil holding capacity for

metal contaminants. In that work, acceptable metal loadings are a function of soil cation exchange capacity. This recognizes that metal availability, either to plant life or to solubilization and leaching, is significant. While plant toxicity and uptake is to be minimized for arable land use purposes, dispersion of metals from the site is of concern where the site is used solely for waste degradation and immoblization.

Because of the higher waste loadings to be expected on a dedicated site, higher cumulative loadings of contaminant are expected and for contaminant dispersion water and soil monitoring is indicated.

4.4 Guidelines for Land Application: Terrain Factors

These guidelines are concerned with ground and surface water protection, and with amenity effects on users of neighbouring lands.

Recommendations from Ontario, Alberta, and EPA give guidelines for siting based on both terrain and surroundings. The EPA recommendation is for a dedicated land application site rather than for agricultural use; the Ontario and Alberta recommendations are for agricultural land.

4.4.1 Ontario

Ontario Guidelines (50): Minimum Distance to Watercourse

Maximum Sustained Slope	For Sewage Sludge Application During May to November Inclusive	For Sewage Sludge Application During December to April Inclusive
0 to 3%	60 m	180 m
3 to 6%	120 m	180 m
6 to 9%	180 m	No sewage sludge to be applied
Greater than 9%	No sewage sludge to be applied unless special conditions exist	No sewage sludge to be applied

Note: The above values are for soils of rapid to moderately rapid permeability. For soils of moderate to slow permeability, the distances should be doubled and spreading should be suspended during March and April when runoff is expected. The footnote from Table 3 (Allowable Duration of Application) should be used to determine the permeability classification.

Distance to Water Wells

The site should be at least 90 m from water wells.

Note: The Implementation Committee has proposed a tentative revision, to Ontario Regulation 824, (now Regulation 309, referring to hauled sewage) which would permit the separation distance to be determined by site specific criteria.

Distance to Ground Water

The ground water table during sewage sludge application should be not less than 0.9 m below the surface, for soils with moderate to slow permeability. For soils with rapid to moderately rapid permeability, the ground water table should desirably be 1.5 m or more below the surface. The position of the water table may be difficult to determine, particularly in fine-textured materials. It is suggested, therefore, that if the position of the water table may be critical at a particular site, the Ministry of the Environment's Regional Ground Water Evaluator should be consulted.

Distance to Bedrock

Sewage sludge application should generally not be allowed where the unconsolidated materials overlying bedrock are less than 1.5 m thick. Under special circumstances, and based on site-specific studies where it can be demonstrated that the risk of ground and surface water contamination is minimal, the recommended thickness of the unconsolidated materials may be reduced.

Distance to Residential Areas and Human Habitations

The site should be at least 90 m from individual human habitations and at least 450 m from areas of residential development.

4.4.2 Alberta

Alberta Guidelines (51): Minimum Acceptable Distances from Specified Features[1]

The following minimum distances are required: it may often be in the interest of the municipality and haulage contractor to exceed these to ensure public acceptance of sludge spreading programs.

Feature	Minimum Distance (m)	Preferred Distance (m)
Rivers[2], Canals[2], Creeks[2], Intermittent Drainage Courses, Lakes, Sloughs, Dugouts	30*	50
Water Wells	20	50
Areas Zoned Residential or Devoted to Urban Use	500*	800
Occupied Dwellings	60*	100
Road Allowances	10	20
Public Building Perimeters	10	30
Public Buildings	60*	100
School Yard Boundaries (School in Session)	200*	500
School Yard Boundaries (School not in Session)	20*	20
Cemeteries, Playgrounds, Parks, Campgrounds	200*	500

1. Greater separation distances may be required based on local topographic and climatic conditions.

2. Distances required are from the major break in slope.

* Distances can be reduced by 67% if sludge is subsurface injected.

4.4.3 EPA Guidelines

The United States Environmental Protection Agency Process Design Manual for Land Application of Municipal Sludge (54) has compiled recommendations for various parameters for application sites. Some of these are listed below. Although these recommendations were prepared for sewage sludge application, they illustrate differences in practice for agricultural and dedicated land disposal.

RECOMMENDED LIMITS FOR DEPTH TO GROUND WATER

TYPE OF SITE	DRINKING WATER AQUIFER	EXCLUDED AQUIFER[1]
Agricultural	1 m	0.5 m
Forest	2 m[2]	0.7 m
Drastically Disturbed Land	1 m[3]	0.5 m
Dedicated Land Disposal	At least 3 m	0.5 m

1. Clearances are to ensure trafficability of surface, not for ground water protection.
2. Seasonal (spring time) high water and/or perched water less than 1 m is not usually a concern (see design chapter for discussion of these limits).
3. Assumes no ground water contact with leachate from operation.

Metric conversion: 1 m = 3.28 ft.

SUGGESTED SETBACK DISTANCES FOR SLUDGE APPLICATION AREAS

	DISTANCE FROM FEATURE TO SLUDGE APPLICATION SITE				
	15 to 90 m[1]		90 to 460 m[2]		>460 m[3]
FEATURE	INJECTION[4]	SURFACE	INJECTION[4]	SURFACE	INJECTION & SURFACE
Residential Development	No	No	Yes	No	Yes
Inhabited Dwelling	Yes	No	Yes	Yes	Yes
Ponds and Lakes	Yes	No	Yes	Yes	Yes
Springs	No	No	Yes	Yes	Yes
10 year High Water Mark of Streams, Rivers and Creeks	Yes	No	Yes	Yes	Yes
Water Supply Wells	No	No	Yes	Yes	Yes
Public Road Right-of-Way	Yes	No	Yes	Yes	Yes

1. 50 to 300 ft.
2. 300 to 1,500 ft.
3. > 1,500 ft.
4. Injection of liquid sludge or surface application of dewatered sludge.

POTENTIALLY UNSUITABLE AREAS FOR SLUDGE APPLICATION

1. Land adjacent to subdivision, schools and other inhabited dwellings.
2. Areas bordered by ponds, lakes, rivers, and streams without appropriate buffer areas.
3. Wetlands and marshes.
4. Steep areas with sharp relief.
5. Undesirable geology (karst, fractured bedrock) (if not covered by a sufficiently thick soil column).
6. Undesirable soil conditions (shallow, permafrost).
7. Areas of historical or archeological significance.
8. Other environmentally sensitive areas such as floodproofing or intermittent streams, ponds, etc.
9. Rocky, non-arable land.

SITING CRITERIA FOR DEDICATED LAND DISPOSAL

Parameter	Unacceptable Condition	Ideal Conditions
Slope	Deep gullies, slope >12%	<3%[1]
Soil	Permeability >1 x 10^{-5} cm/sec[2]	$\leq$ 1 x 10^{-7} cm/sec[3]
	<0.6 m (2 ft.) in-situ thickness	>3 m (10 ft.) in-situ thickness
Surface Water (distance to)	<92 m (300 ft.) to any pond or lake used for recreational or livestock purposes, or any surface water body officially classified under state law	>305 m (1,000 ft.) from any surface water body
	In special flood hazard areas or recognized wetlands	>61 m (200 ft.) from intermittent streams
Ground Water	<3.1 m (10 ft.) to ground water table (wells tapping shallow aquifers)[4]	>15.3 m (50 ft.) to water table
Wells (potable)	Water supply wells within 305 m (1,000 ft.) radius	No wells within 610 m (2,000 ft.) radius

1. Ideal slope depends on solid content (TSS) and sludge application method.

2. Pervious soil can be used for DLD if appropriate engineering design preventing DLD leachate from reaching the ground water is feasible.

3. When low permeable soils are too close to the surface, liquid disposal operation can be hindered due to water ponding.

4. If an exempted aquifer underlies the site, poor quality leachate may be permitted to enter ground water.

5. TECHNICAL AND DESIGN CONSIDERATIONS

5.1 Introduction

The criteria considered in a decision to dispose of a waste by land application must include both the characteristics of the waste and the nature of the proposed site. The decision must take into consideration all the factors that a standard landfill must, as well as many that a conventional farmer would. The interaction between waste characteristics and site conditions must be considered, and legal land use requirements must be met.

5.1.1 Regulatory Requirements

Use of land for waste disposal falls under environmental and waste disposal/waste management legislation. In Canada, there are no regulations or published guidelines specific to hazardous waste land application, but procedures for obtaining approval would follow those steps laid out for siting a waste disposal facility. Guidelines for the site terrain may parallel those for agricultural sludge use practice.

5.1.2 Public Participation

Since a hazardous residues land application operation is a waste disposal facility, it would be treated as such insofar as public participation in site selection and approval is concerned. While there are significant differences between the operations carried out during land application and other

application and other disposal methods, many of the public concerns will be the same. Adjacent property users are normally concerned with odours, disease, organisms, noise, dust, traffic and aesthetic factors where a disposal site is under discussion. The effect of the facility on resale value of property is often the major concern. Although proper design and management will serve to minimize these factors, as will a buffer zone around the site, project proponents must demonstrate the suitability of the project in terms of economic and technical feasibility, and environmental impact.

5.1.3 Types of Land Application

Land application has been conducted both as a waste disposal method and a soil amelioration technique. Sewage sludge has been applied to agricultural land, forest plots, for reclaiming "disturbed land" (where, for example, mining operations have taken place) and on "dedicated" land used only for disposal (54).

Agricultural and forest use of sewage sludge can satisfy both nutrient and disposal needs, thereby providing advantage to both the generator and the user. Use of sludge for reclaiming land provides a disposal means for the generator, with a potential aesthetic/environmental benefit at the application site. Finally, land application of wastes on dedicated land is solely a disposal method, and the land is used only for this purpose until it is no longer usable or desirable as a disposal site. No vegetation is grown. Generally, much heavier sludge loadings are usable with dedicated land disposal than with other land application methods.

For disposal of hazardous wastes, only land application on dedicated land is considered here. This is both because the hazardous components of the waste would bar any other use of the land during the disposal process, and to maximize waste destruction capacity of the site.

5.2 Climate Considerations

5.2.1 Temperature

The area required to degrade a given quantity of waste will depend directly upon the temperatures at the site. Degradation in the soil is approximately proportional to the temperature above a minimum growing temperature, commonly considered to be considered to be 5°C in this part of the world. To estimate the effective growing season from the standpoint of temperature, the factor "degree-days above 5°C per year", or "growing degree-days" may be used.

When the average temperature is below 5°C, wastes applied to the soil will not be effectively degraded. Combined with runoff potential when waste is applied to frozen soil, this effectively limits the application season.

Growing degree-days data for over 2000 locations in Canada are available as an aid in estimating the temperature history of a specific site (57).

5.2.2 Precipitation

Waste application rates, based on precipitation data, are discussed in Section 2. Generally, control of runoff and

leachate will be the major consideration regarding water balance at a site. These factors are increased by precipitation, and any design for surface and ground increased water control will need to consider precipitation. Other precipitation-based factors in site selection or design are maximum 24 hour rainfall to be expected and number of days with rainfall per year. The former will affect the design capacity of the water collection or treatment system, while the latter is a factor in the time available for spreading the waste and cultivating it into the soil.

Approximate ranges for these variables are shown in Appendix 16 for each province. Precipitation history for locations across Canada is available from Environment Canada (58).

Temperature and precipitation provide the two major constraints on time available for land application. The former affects the degradation and, possibly, runoff rates, and the latter affects both water balance and the mechanical ability to apply to the site.

5.3 Drainage

Where annual precipitation and (water content of waste times annual thickness applied) is greater than the annual evaporation rate from the site, the excess must be removed from the site. This can occur either by infiltration to ground water or by interception by a drainage system.

For agricultural purposes, drainage is used to maintain the water table at a level advantageous to crop growth. For waste disposal, the purpose is different. It is necessary,

for degradation and fixation purposes, that the water table be low enough that the working layer of the soil remains aerobic.

In addition, for effective treatment of the aqueous component of the waste, the aerobic zone must be maintained to a minimum depth of 0.6 to 1.0 m. A water table depth of at least a meter at all times is therefore desirable. Where the water table is closer to the surface than this at the site, due either to the height of the natural water table, precipitation, or waste loading, drainage is required to provide a sufficient aerobic zone.

Drainage may also be considered in arid areas to reduce salinity, and to permit the use of a smaller land area for disposal. The depth and spacing of drains have, in agricultural practice, generally been determined by experience for specific site and soil conditions. Drainage of landfarm sites in Canada is less common. Plastic pipe or clay tile, 10 to 20 cm diameter, have been used, buried at depths from 1 m to 3 m (54, 59). Spacing of drains ranges from 15 m, corresponding to clay soil, to 120 m, for sandy soil. To determine spacing the following equation may be used:

$$S = \left[\frac{4KH}{LW+P}(2d + H)\right]^{1/2}$$

where:

K = horizontal hydraulic conductivity of the soil (m/d)
H = height of ground water "mound" above drains (m)
LW = annual loading rate, expressed as a daily rate (m/d)
P = annual precipitation, expressed as a daily rate (m/d)
d = distance from drains to underlying impermeable layer, m

Using a small value for "d" will produce a conservative (narrow) estimate for drain spacing "S". If values of S between 15 and 50 m are obtained, underdrains will definitely be needed. Values of S over 160 m indicate that grcund water mounding should be evaluated to determine whether drains are needed (54).

5.4 Site and Terrain Factors

Site characteristics are the most significant factor in the performance of a land application site. Constraints on operation will be imposed by the physical nature of the site, such as soil type, soil depth and terrain. Surface and ground water conditions and distance from potable water wells will be a major factor in site selection and may possibly control any operations.

5.4.1 Soil Type

The limitations imposed by soil type for sewage sludge application have been relative rather than absolute; more waste can be applied to soils with higher cation exchange capacity (CEC). Although metals are not specifically bound to the minerals' exchange sites, the CEC is a useful indicator of

the "binding property" of the soil. Another key property is the permeability of the soil, with an optimum range for waste disposal falling between impermeable soils like clays and permeable ones like sand. Soil characteristics and suitability are discussed in detail in Section 2.

5.4.2 Terrain and Environs

Guidelines for Alberta, Ontario and the United States terrain selection are given in Section 4. Although the former are based on agricultural sludge spreading practice, the principles are applicable to hazardous waste.

The suitability of a site, based on these guidelines, will be limited by the factors of:

- slope
- soil type and permeability
- distance from watercourses and wells
- distance from habitations, schools, etc.
- distance from ground water
- distance from bedrock
- and possibly others peculiar to the area.

These factors are interactive in terms of site selection; for instance, distance to watercourses must be greater where the soil is less permeable and/or the slope is steeper, due to increased runoff potential. Similarly, a high ground water table is less of a constraint with low permeability soils, from the standpoint of ground water contamination.

5.5 Waste-Specific Factors

5.5.1 Quantity

The quantity of waste that maybe applied to soil is highly variable, depending on waste composition and degradables content, and on site characteristics. EPA has cited annual application rates from 12 dry tonnes/ha to 2,250 dry tonnes/ha (54). Higher application rates were practicable using dewatered sludge, with mechanical incorporation into soil, in areas of low precipitation and without ground water contamination constraints.

For oil sludges, CONCAWE (60) has suggested as a starting point oil loadings of 50 to 100 tonnes/ha/year. One hundred tonnes per ha. corresponds to about 4-1/2-5% oil in the top 15 cm of soil; the practice at some Canadian refineries has been to add more sludge when the oil concentration drops below 1%. The quantity of sludge that would contain this much oil is highly variable, and in the case of low oil content sludges, volume constraints would limit the amount to be applied. Most landfarms are said to use 1 cm to 8 cm coatings, with thinner and more frequent coatings preferred (61). Very high loadings may result in anaerobic soil conditions, which would inhibit degradation almost indefinitely.

Where one component of the waste degrades slowly, its concentration may be the limiting factor. An example is the asphaltene content of some petrochemical wastes, which degrades much more slowly than aliphatic fractions.

Significant amounts of disposal efficiency data are available only for petroleum and oily wastes. Such work has been

conducted over a range of sites in North America from the southern United States to northern Alberta. Some results are summarized below:

Waste	Location	Initial Oil Content of Soil (g/kg)	Oil Degraded g/kg Soil	Oil Degraded L/ha	Ref.
Refinery Oil Waste	Montana	10	7	2,100	(62)
	Oklahoma	50	9	2,700	(62)
	Texas	100	165	48,800	(62)
Petroleum Crude	Oklahoma	50	17	50,000	(62)
	Various U.S.	10	14	41,000	(62)
Lube Oil	Various U.S.	20	18	53,000	(62)
	New Zealand	20	27	80,000*	(62)
		50	38	12,000*	(62)
		70	69	204,000*	(62)
		90	454	1,342,000*	(62)
Waste Vacuum Pump Oil	Tennessee	70	171	505,000*	(62)
Fuel Oil	Texas	100	311	919,000*	(62)
	Various	20	20	59,000*	(62)
Oily Waste Sludge					
(Lloydminister)	Laboratory	28-38	6- 8	-	(63)
(Drayton Valley)	"	27-29	17-17	-	(63)
(Grande Prairie)	"	28-29	18-19	-	(63)
(Brooks)	"	42-47	11-13	-	(63)
(Brooks)	"	11-13	4- 5	-	(63)
(Lloydminister)	Lloydminister, Alberta (test plot)	9-31	2.6-9	8,300	(63)
(Drayton Valley)	Drayton Valley Alberta (test plot)	84-156	40-73	13,000	(63)
(Grande Prairie)	Grande Prairie, Alberta, (test	18-44	12-29	44,000	(63)

Several factors can be seen to influence the degradation rate. These include:

a) Waste loading. Within the range tested, the higher the loading, the more waste is degraded. This effect probably has a ceiling; for oily wastes, near 10% oil.

b) Site location. Degradation is faster in warmer climates.

c) Waste composition. In the Alberta tests it was noted that the heavier Lloydminister oil contained a higher proportion of aromatics than the other test sludges. Differences among different types of waste oil are also apparent.

Effects not reported, but which may have an effect, will include:

- rainfall
- fertilizer use
- waste application frequency
- cultivation technique and frequency, etc.

Leather waste sludges have been applied to soils in California in test plots at quantities upto 570-1,100 tonnes/ha dry weight (see Section 6). Complete degradation is slower with very heavy loadings, although the mass degraded per unit area is higer than with light loadings. This is part due to difficulty in incorporating large quantities of sludge into the soil; considerable quantities remain undispersed.

5.5.2 Water Balance

Waste treatment sludges are generally aqueous in nature, and continued application of such wastes will mean significant additions of water to the site. In arid climates much of this may be lost by evaporation, but in general a product of the land application process will be waste water. Decisions as to the necessity and means of treatment of this aqueous waste will have to consider factors and options such as:

- composition and concentration
- on-site containment and treatment
- controlled discharge
- leachate interception and treatment (subsurface drainage)

The disposal capacity of a site will be limited by its water retention both during and after the spreading operation. With the loading rates practical for a dedicated site, a considerable quantity of water is expected to leave the site, and normally this will include surface runoff. Design considerations for waste water control will be similar to those for sewage sludge land application. Specific site design criteria, are addressed in Land Application of Municipal Sludge, Process Design Manual, EPA-625/ 1-83-016 (54).

5.5.3 Nutrients

Hydrocarbon waste disposal may require supplimentary nitrogen; quantities of 1 ton/acre/year (2.3 Mg/ha/year) as ammonium nitrate or urea have been used (64). Where wastes contain significant quantities of nitrogen, monitoring should

ensure that there is neither excess nitrogen bodies leaving the site nor deficiencies in nitrogen impeding biodegradation of the waste.

Recommendations for nutrient level have suggested C:N ratios of 10:1 to 33:1; 10:1 is considered heavy (61). Potash and phosphate levels are much less sensitive to the biological activity rate, and additions are much less likely to be necessary than is the case for nitrogen. pH control - through lime addition - may be necessary initially, and occasionally thereafter. pH must be maintained above 6.5 for good degradation performance and metal precipitation.

5.5.4 Degradability of Waste

While land application will only be considered for wastes that are degradable or irreversibly fixable in soil, rates or conditions of degradation for "suitable" wastes may vary widely. The relative intractability of asphaltenes in petroleum wastes has been cited as a limiting factor for disposal of certain wastes (61). Although the total waste level in the soil may be at equilibrium, the concentration of the intractable component may be increasing. In other cases, a particular step in the degradation of the waste may not occur without provision of special conditions. It is known, for example, that the insecticide DDT does not degrade to DDD except under anaerobic conditions, which seldom apply under land application conditions (65). To achieve this step in the process, preliminary treatment such as composting may be necessary. Without this provision the waste would not be eligible for land appication.

Similarly, the possibility may exist for the formation of more toxic intermediates. Mercury compounds may, under some conditions, form organo-mercury compounds. The pesticide Swep (methyl 3,4-dichlorocarbanilate), may be converted into azobenzene derivatives, some of which have shown carcinogenic activity (66). Such wastes are also ineligible for land application as a treatment means.

5.6 Other Factors

5.6.1 Safety of Workers Applying Waste

Spreading of residues may result in skin contact with waste or inhalation of toxic vapours or mists. The process of discing or rototilling the (dried) wastes into the soil is often very dusty, and workers are exposed to the waste-containing dust. Inhalation and skin contact may be minimized by appropriate use of respirators, boots, gloves, and other equipment as required.

5.6.2 Dust and Vapour from the Landfarm

Dust and vapour raised by cultivating and spreading of residues may also affect neighbouring properties. Unlike the case of site workers, it is impractical to use personal protective equipment to protect the public. Off-site air emissions must therefore be minimized. This is the major reason for establishing a buffer zone around the site. With sufficient dilution, neither vapour nor dust will result in a health hazard. This emphasizes the importance selecting a site amid appropriate surroundings. In the midst of either

industrial or agricultural land, these emissions would be of less concern than if the site were adjacent to residential or commercial property.

5.7 Monitoring Requirements

The media most vulnerable to contamination by a land application site are ground and surface waters. Monitoring should be directed to detect trends to such contamination so that preventive action may be taken. In general, monitoring requirements would include:

- monitoring of applied residue: total quantities and contaminant levels;
- monitoring changes in the soil of the site, both physical and chemical;
- monitoring of surface runoff and nearby surface waters;
- monitoring ground water quality;
- air monitoring for odour, dust or aerosol emissions.

6. DETAILED STUDY OF SPECIFIC HAZARDOUS WASTES

6.1 General

Section 3 of this report provides general criteria for determining a particular waste's suitability for land application. Within the boundaries of these criteria, some wastes are more suitable than others. In addition, since this study concerns itself only with hazardous wastes, non-hazardous wastes, such as are derived from the food and distilling industries, will not be considered. It may be noted, however, that these wastes do meet the criteria and are ideally suited for land application.

For other wastes, often existing information is based on laboratory studies or technology from other similar wastes. Pilot projects will be required to assess the suitability of any hazardous waste for land application if this has not been previously done. Additionally, the constraints of Canadian weather patterns impose other limitations which can only be determined by experimentation.

6.2 Selection of Wastes for Detailed Study

The inventories discussed in Section 3 present data for liquids (solutions), sludges, and other wastes (higher percentage of solids). In the initial selection process used in this report, liquid wastes were not considered for the following reasons:

- Solutions imply the presence of high concentrations of dissolved constituents (e.g. NaCl, NaOH, H_2SO_4, etc.). These types of wastes can be adequately treated

with waste water technologies, including physical/ chemical treatment followed by one or more land disposal techniques.

- Solvents were not considered since most solvents are volatile, and application to soil could create serious air pollution problems, especially if highly volatile toxic constituents are present.

The selection process therefore focused on sludges and other wastes, given the following criteria:

- Sufficient quantities of the wastes must be generated to warrant further study.

- Wastes from petroleum refining have not been selected since numerous land application projects have involved those wastes.

- Some information on land application of the waste should be available, if not for the specific waste, for another waste whose similarity is such that parallels can be drawn.

- Pilot land application demonstration projects for the waste would be helpful.

From these considerations, the following wastes were chosen for more detailed study:

1. Leather tanning wastes, including processing sludges (dehairing and chromium laden sludges) and certain solid wastes (shavings, trimmings, buffing, dust, etc.).

2. Paint formulating wastes, including oil and water-based solid wastes and processing sludges.

3. Wood preserving wastes, including process sludges and solid wastes that contain creosotes, pentachlorophenols, and inorganics such as copper, chromium and arsenic.

These wastes are considered hazardous, having similar characteristics to some of the Class 8.3 wastes of the Transportation of Dangerous Goods Regulation.

6.3 Leather Tanning Industry

6.3.1 Manufacturing Description and Waste Production

Leather tanning refers to the conversion of animal skins or hides into leather. Tanning is essentially the reaction of collagen within the hide or skin with tanning agents which help to stabilize or preserve the skin and make it useful. The predominant agents used by the industry are trivalent chromium and vegetable tannings extracted primarily from tree bark. Others include alum and syntans (62).

The major processes by which leather is manufactured are:

- beamhouse operations, in which the hides or skins are washed and soaked and the attached hair is removed;

- tanyard processes, in which the tanning agent reacts with and stabilizes the proteinaceous matter in the hides or skins; and

- retanning and wet finishing processes, which accomplish further tanning by chemical agents, such as dyes, lubricants, and various finishes.

Water is essential to leather tanning and is used in virtually all manufacturing processes.

Waste water of varying quantities and pollutant loads originate from every wet process in a tannery. Tannery waste waters contain soluble and suspended organic matter, including:

- Oils and grease
- Suspended and dissolved solids
- Inorganics such as salt
- Chromium salts
- Sulfides
- Ammonia
- Small quantities of nutrients

In addition to chromium, other pollutants are present in the various waste streams which originate from the various chemical processes. The constituents enter the waste streams as proteinaceous matter, hair, tissues, unfixed chemicals, tanning agents, extracts, dyes, pigments, dirt, grit and manure (67).

6.3.2 Waste Characteristics

Toxic pollutants present in the raw waste water generate from this industry are presented in Appendix 17. Those which are found in high concentrations and/or are present in many of the industry's waste waters are:

- Toxic inorganics
  - chromium
  - lead
  - copper
  - zinc

- Toxic organics
  - phenol
  - pentachlorophenol
  - 2,4,6-trichlorophenol

Sludge characteristics from various tannery sludges are presented in Appendices 18 and 19. Appendix 18 examines the inorganic content of two sludge types: dehairing (hairburn) and chrome sludge. Note that median organic carbon concentrations (shown as TOC on the table) are 16.4 and 34.0% for the hairburn and chrome sludges, respectively (68). The data presented in Appendix 19 examines the extractable organic fraction in terms of aliphatic and aromatic, and polar versus non-polar extractables.

6.3.3 Degradation Pathway and Environmental Fate

Tannery sludges have been land applied in the United States and other countries (69), but only limited data on their environmental fate is available (69, 70, 71). These sludges are rich in proteinaceous residues and organic carbon Appendix 18 which are available for microbial decay, making land application a viable disposal alternative.

Because tannery wastes contain organic nitrogen in the form of stabilized collagen, they have been used as an organic nitrogen fertilizer supplement and as a soil amendment. As a result of the chromium in the leather, the nitrogen is released more slowly than from nitrogen fertilizers derived from other proteinaceous wastes (69).

Buffing dust slurry collected from a settling basin has been applied to an agricultural land application site located in Pennsylvania since 1961 (71). It was used primarily as a nitrogen supplement and organic amendment to the soil. Analysis of the surface soil and vegetation for nutrient and trace metals showed an overall increase in total nitrogen, water-soluble potassium, and acid extractable nickel, lead, and chromium in the soil. Heavy metal uptake in the vegetation was significantly higher in the waste treated plot than in the control plot, but this uptake was attributed to selective absorption in the roots and foliage, not in the grain. The data suggested that the tannery waste disposed at this site may be a good source of available nitrogen.

The majority (86%) of organics present in tannery wastes have been identified as non-volatile polar and aliphatic hydrocarbons (Appendix 19). It is expected that volatilization would not be a major elimination mechanism, except possibly during the summer months. Biodegradation and to a small extent photodegradation are therefore the most likely means of waste reduction.

The primary environmental concern in land application of leather tanning wastes is in the immoblization of the heavy metals which are present, particularly chromium, lead, copper and zinc. Chromium is by far the most significant due to its

concentration and potential for toxicity. Chromium contained in tanning sludges is in the trivalent form and is relatively immobile and inert in soils (72).

In dehairing operations, hair is removed from hides with a depilatory (NaHS), lime, and soda ash. The waste stream from the operation goes to collecting tanks where manganese sulphate is added as a catalyst for the oxidation of the remaining sulfide. If dehairing are combined with tanning sludges, it has been suggested that the manganese can oxidize the Cr(III) to the hexavalent form (68). Cr(VI) is toxic and quite mobile in the soil. Under aerobic soil and neutral pH conditions, however, hexavalent chromium is rapidly converted to the trivalent state (72).

The other consideration for land application of wastes that contain heavy metals is the sorption capacity of the soil. Once again, this soil property is site-dependent, and must be evaluated on a site-by-site basis. Section 2 discusses the interactions of metals with soil, and conditions leading to their immobilization.

6.3.4 Current Demonstration Project

The U.S. EPA is currently funding a 5-year study on the land treatment of tannery sludges with the following objectives (69):

- to assess the potential adverse and beneficial environmental impacts of land treatment;
- to determine the accumulation and movement of contaminants in the soil;

- to monitor for the transformation of Cr(III) to CR(VI);

- to optimize site design and operational procedures;

- to estimate the cost of full-scale practices.

The land application site lies within the Scott Creek Valley in western Santa Cruz County, California.

The study is currently in its third year. Hairburn, chrome and mixed (30% hairburn, 70% chrome) sludges have been applied on seven test plots (each at 0.2 ha) at application rates ranging from 0 to 604 wet tonnes/ha. Total Cr(III) loadings range from lows of 20 and 38 kg/ha on two hairburn-only plots to a high of 4,600 kg/ha on one mixed sludge plot. Total nitrogen loadings have been high, ranging from 1,600 to 7,200 kg/ha, but available nitrogen calculations show lower totals, ranging from 492 to 2,050 kg/ha. The degradation rate of the nitrogen, however, was not known; available nitrogen was assumed at 50% of the ammonia nitrogen plus 20% of the total Kjeldahl nitrogen (TKN) for the first year, 10% for the second, 5% for the third, and 3% for the following years.

Preliminary data analyses suggests the following:

- No Cr(VI) has been detected in any of the plots at depths to 90 cm.

- Cr(III) movement through the soil profile on any of the plots has not been observed to any significant degree.

- Nitrate levels in excess of 500 mg/l have been observed in some of the high nitrogen-loaded plots, indicating that the N application rates have been excessive.

6.3.5 Environmental Effects

Leather tanning wastes have been effectively land applied in the United States and other countries. Due to incomplete data concerning waste application rates and site monitoring, the assessment of the environmental effects of land application is not conclusive. The nature of the waste material may allow for use as a soil amendment and organic nitrogen fertilizer supplement. The stabilization of the collagen by the tanning agent allows nitrogen to be released slowly, reducing the potential for harmful environmental effects such as development of anaerobic conditions and production of (highly mobile) nitrates. Vegetation also helps to offset the formation of nitrate by removing nitrogen. Application rates should be maintained on the conservative side to minimize changes in nitrate production.

The application of leather tanning wastes could however have potentially damaging environmentally effects. Chaney (73) warns against applying both dehairing and tanning sludges to the same area, in order to prevent the production of hexavalent chromium. Hexavalent chromium is toxic (74) and highly mobile in the soil medium, and is available for uptake by microorganisms or migration to surface or ground waters. Ross et al. (75) found that even at 7.5 ppm in growth media, Cr(III) was toxic to the soil bacteria Pseudomonas and Nocardia. However, in soil systems, Cr(III) forms precipitates readily with carbonates, hydroxides, and

sulphides (76). The precipitation reactions are favoured by pH values greater than 6. Data from Wentink and Edzel (77) show that different soils were capable of almost 100% retention of Cr(III).

Leather tanning wastes also contain a high BOD. At high application rates, this may result in the development of anaerobic conditions. Some organic compounds formed under these conditions are toxic to soil microbes. Any organic acids formed depress the pH of the soil, which increases the mobility of heavy metals through the soil profile.

Soluble salts present in leather tanning sludges can be phytotoxic until leached from the surface soil. Salts also lead to the degradation of soil properties by decreasing permeability and enhancing crusting and can also migrate into ground or surface waters.

6.3.6 Conclusion

Leather tanning sludges can be successfully treated by land application. The ongoing U.S. EPA demonstration project suggests that the trivalent form of chromium does not revert to the hexavalent state even in the presence of high concentrations of manganese and iron. Proper site management is mandatory, however, for the control of excessive nitrogen buildup and resultant nitrate leaching. This can be accomplished by the installation of monitoring points.

The degradation rate of hairburn and chrome sludges is not known; but based on three years of data from the demonstration project, it appears that decomposition is faster than for municipal sewage sludge.

6.4 Paint Formulating Wastes

6.4.1 Manufacturing Description and Waste Production

In the paint formulating industry few raw materials, if any, are manufactured on-site. The major products are household sale paints, industrial sales paints, varnishes and lacquers. In addition, the industry also produces related products such as putty, caulking compounds, sealants, paint and varnish removers, and thinners (78).

Paints may be either solvent-based or water-based, but there is little difference in production methods for the two product types. The major production difference between the two is in the carrying agent. Solvent-based paints are dispersed in hydrocarbon mixtures, whereas water-based paints utilize water with a biodegradable surfactant as the carrying agent.

Paints are generally produced in batches in large mixing tanks or tubs. After production of a particular formulation, the tanks must be cleaned to prevent contamination of the following formulation. It is at this operation where solid wastes and waste waters are generated.

With solvent-based paints, the cleanup process consists of allowing the paint to drain by gravity, and (optionally) removing the "clingage" with a squeegee. The tanks are then flushed with solvent until clean. Dirty solvent is handled in one of the following ways.

- Used in the next batch as part of the formulation.

- Placed in drums to be sold for solvent recovery and resale.

- Collected in drums to be decanted for subsequent reuse for tank cleaning. The solvent is reused until only sludge remains. The generated sludge is usually disposed in a landfill.

As for solvent-based paint operations, as much of the water-based product is removed from the sides of the tank as possible before cleanup starts. Cleanup is done by washing the sides of the tanks with pressurized water. Wash water may then be:

- Collected in holding tanks and treated before discharge.
- Collected in drums and disposed in a landfill.
- Discharged directly to a sewer or receiving stream.
- Reused in the next batch as part of the formulation.
- Reused in the washing operation.

6.4.2 Waste Characteristics

The industry generates a very low volume of waste water, mainly from the water-based products. Those shops that produce only oil-based paint generate virtually no waste water. The waste water flow is, however, extremely potent, and can have a serious deleterious effect on any biological waste water treatment system, including those of municipalities. Land application might therefore be a desirable disposal alternative.

Sludge is produced from the production of both solvent-based and water-based formulations. Sludge produced from solvent-based formulations is generated directly from cleaning operations. Sludge from water-based formulations is derived from pretreatment of the waste stream by physical/chemical means, and/or settling.

The pollutant characteristics of the raw waste water and sludge for the industry are presented in Appendices 20 and 21. These data incidate that the raw wastes contains substantial concentrations of heavy metals, particularly lead, mercury, nickel and zinc, as well as toxic organics. The wastes also have high COD, total solids, and concentrations of other non-toxic materials.

Fifteen toxic pollutants were observed to be in significant quantities and/or occurred frequently in both the raw waste water and the sludge generated from the paint formulating industry. The toxic organics which are characteristic of the industry are:

- Benzene
- Ethylbenzene
- Di(2-ethylhexyl) phthalate
- Methylene chloride
- Tetrachloroethylene
- Toluene

The toxic inorganics which are common to the industry are:

- Arsenic
- Beryllium
- Cadmium

- Chromium
- Copper
- Lead
- Mercury
- Nickel
- Zinc

6.4.3 Degradation Pathways and Environmental Fates

The fate of the abovementioned pollutants in the soil environment is dependent upon many factors, particularly the method of waste application, the characteristics of the pollutant and the characteristics of the soil.

The characteristics of the waste also determine its eventual environmental fate. Generally, inorganics will be immobilized in the soil, while organics will be immobilized and eventually degraded (with the exception of recalcitrant compounds) to a less toxic or non-toxic product by physical, chemical or biological means. Organic compounds can be considered by chemical classes, since similar molecules commonly degrade by similar pathways. The particular waste from this industry is comprised of halomethanes (methylene chloride), aromatic solvents (benzene, toluene and ethylbenzene), chlorinated ethylenes (tetrachloroethylene), and semivolatiles (di(2-ethylhexyl) phthalate).

Organic pollutants from paint formulating have been described as susceptible to microbial decay (72). The rates of degradation for many of these pollutants have not been measured, particularly in multi-species environments. It is known, however, that aromatics generally decompose slower than unbranched alkanes.

Studies (72, 79, 80, 81) confirm that alkylbenzenes and phthalates decompose readily in single-species experiments, and it is anticipated that, when present at low to intermediate doses in soil, the large mixed microbial population will degrade these compounds readily.

Volatilization can be a significant volume reduction method for paint formulating wastes once they are applied to land. Halomethanes, aromatic solvents, and chlorinated ethylenes all contain extremely volatile compounds. The degree of volatilization is dependent upon method of application, ambient temperatures, and wind speed. Periodic disking would improve volatilization and mixing resulting in a more rapid degradation.

Sorption of organics by humic and clay colloids is yet another mechanism. Sorption reduces the mobility of organics and inorganics in the treatment zone, thereby prolonging treatment time, and reducing the potential to leach into ground water. Due to the relative hydrophobicity of aromatic compounds, they are rapidly adsorbed by colloids.

Heavy metals are present in paint formulating wastes in fairly high concentrations. The heavy metals of concern in these wastes are arsenic, beryllium, cadmium, chromium, copper, lead, mercury, nickel, and zinc. Effective removal of these metals depends upon characteristics of the soil, which must be determined prior to considering land application as a treatment. Little specific information on metal immobilization exists, so treatability tests should be designed to determine the mobility of the metals of concern in a given soil environment.

Generally, soil to which these wastes are applied should have a high cation exchange capacity (CEC $\geq$15). High CEC values are typical of soils which have a significant amount of clay or other high-surface area particles such as humic substances. Heavy metal cations are strongly adsorbed by organic matter. This reduces their mobility and decreases their availability to soil organisms.

Most heavy metals will remain in the treatment zone in the soil under aerated conditions. Metals may be sorbed chemically by organic matter or oxides; electrostatically sorbed on exchange sites of waste constituents or soil colloids; solid phase insoluble precipitates; or in the soil solution.

6.4.4 Environmental Effects

Application of high doses of paint formulating wastes may result in phytotoxicity, if vegetation is present, or toxicity to soil organisms.

High concentrations of aromatics can induce changes in the physical properties of soils. Aromatics have been shown to induce hydrophobicity in soils, resulting in changes in water absorption by soils for several hours after the substance was introduced (72).

Most environmental effects concerning application of paint sludges involve the high concentrations of heavy metals contained in the wastes. The application of organics is not as environmentally significant due to the volatility of the compounds, and their relative ease of biodegradation. Once heavy metals are applied, their environmental fate is critical so that the soil is not irreversibly damaged.

Heavy metals in the soil will result in mortality to some soil microorganisms, including organisms important in the degradation of the toxic organic pollutants. Synergistic effects among the various pollutants may also affect the soil microbiology. Since the interactions are quite complex and depend on site characteristics, experimental testing prior to land application and careful management once application begins are important.

6.4.5 Conclusion

Due to the relative ease of biodegradation of those toxic organics present in paint formulating wastes, and the fact that metals can be immobilized in soil environments, these wastes are potential candidates for land application. However, prior to waste application, degradation rates of organics and mobilization of inorganics should be investigated in a laboratory or other carefully monitored setting, and careful management techniques for the land application site are mandatory.

6.5 Wood Preserving Industry

6.5.1 Manufacturing Description and Waste Production

The wood preserving industry is made up of establishments which apply chemical treatment to wood, in order to protect against decay, fire and insects. The major types of preservatives used in wood preserving are creosote, pentachlorophenol (PCP) and various formulations of water-soluble inorganic chemicals, the most common of which are the salts of copper, chromium and arsenic.

Fire-retardant formulations are principally salts of borate, phosphate, and ammonium compounds (82).

The wood preserving process consists of two basic steps, conditioning the wood to reduce its natural moisture content, thereby increasing its permeability; and impregnating the wood with the preservative. The industry has been subcategorized into plants that utilize a steaming process, and those that use a process known as boultonizing for conditioning. In the latter process, the wood is heated in an oily preservative under reduced pressure to rduce its moisture content. Since boulton and steaming plants use the same types of preservatives, the waste waters generated by the two types of plants contain similar contaminants.

The main source of waste water generation from wood treating plants is conditioning process. Some waste water also results from the drainage of the preservative from the wood after treatment. Due to the biocidal nature of the preservatives used in the treatment, these waste waters are difficult to biodegrade. Although the industry as a whole produces a significant quantity of waste water, each individual plant produces a fairly low volume.

Waste water treatment is usually by a physical/chemical means, often followed by treatment in an aerated lagoon. The most common treatment schemes are gravity oil-water separation followed by chemical flocculation and slow sand filtration, gravity oil-water separation followed by biological treatment, and no-discharge evaporation systems.

Each of these treatment methods results in sludge containing polynuclear aromatic hydrocarbons, known to be toxic,

potentially mutagenic (83), and carcinogenic. As a result, the U.S. Environmental Protection Agency listed bottom sediment sludges from wood preserving plants as a hazardous waste.

6.5.2 Waste Characteristics

Analytical characteristics of raw effluent and sludge generated from aerated lagoon bottom sediments are provided in Appendices 22 and 23 respectively. These indicate that, in addition to the toxic organic compounds mentioned previously, the waste streams contain substantial concentrations of heavy metals. The toxic pollutants of concern generated by the wood preserving industry are:

- Toxic inorganic compounds
  - Arsenic
  - Copper
  - Chromium
  - Nickel
  - Zinc

- Toxic organic compounds
  - Polycyclic Aromatic Hydrocarbons
    - Acenaphthene
    - Anthracene/phenanthrene
    - Benzo (a) anthracene
    - Benzo (a) pyrene
    - Chrysene
    - Fluorene
    - Pyrene

- Phenolics
  - 2-Chlorophenol
  - 2,4-Dimethylphenol
  - Pentachlorophenol
  - Phenol
  - 2,4,6-Trichlorophenol

6.5.3 Degradation Pathways and Environmental Fates

The major classes of toxic organic pollutants present in wood preserving wastes are phenolics and polycyclic aromatic hydrocarbons. The information available on the fate of these constituents in soils is relatively small. However, interferences from experiments in which single toxic organic compounds have been applied to soil can be made in order to assess the practicability of land application as a treatment alternative.

In a study conducted by Alexander (84), the rate of degradation of pentachlorophenol (PCP) and other substituted phenols in a soil environment was determined. All of the phenolic compounds degraded, with rates dependent on the chemical structure and substituent location on the ring. Phenolic rings with substitutions on the 2, 4, and 6 positions degraded within two weeks, whereas substitutions on the three and five positions resulted in a delay of ring cleavage to ten weeks.

Soil conditions were found to play an important role inthe degradation of substituted phenolics (84). Pentachlorophenol and other phenolics were more rapidly metabolized under conditions of flooded soils than those of drained soils. The

half-life for PCP at the 100 ppm level in soils which were well drained was approximately 40 days at 30°C, compared to 14 days for flooded soils.

Microorganisms have been isolated from soil which multiply on simple aromatic compounds containing up to 3-ring membered polycyclics, such as phenanthren and anthracene, as the sole carbon source (72). The 5-ring membered polycyclics are not known to be metabolized, perhaps due to their low solubility in soils, making these compounds unavailable for microbial uptake. However, these compounds are not biologically inert, and may be co-metabolized with biodegradable compounds by microbes which exude extracellular encymes.

The microbial degradative pathway of polycyclic aromatic compounds has been described by Jeffrey et al. (85). PAH is degraded by an enzyme, oxygenase, which converts these compounds to unstable cyclic peroxide. The cyclic peroxide is subsequently oidized to cis-glycol, which is available for further decomposition.

The literature indicates that phenolic and polycyclic aromatic compounds present in wood preserving wastes are subject to microbial decomposition by bacteria (86, 87, 88) and fungi (89). In a mixed and evolving microbial fauna found in a land application operation, these compounds should be degraded relatively easily.

Other possible mechanisms for the degradation of toxic organics in wood preserving wastes are volatilization and photodecomposition. Both of these mechanisms contribute to the reduction of the waste load in a land application site, but their effects are not a pronounced as biodegradation.

Phenols, phenolics and PAH have relatively low volatility. Volatilization is thus expected to be negligible during the winter, and significant only during the summer. Photodecomposition is also a seasonal phenomenon and only affects the wastes located in the top few centimenters of soil.

Phenolic and polycyclic aromatic hydrocarbons should have a limited mobility in soils due to sorption.

Thompson and Dust (90) monitored total phenolic content of water collected at various soil depths following application of creosote-laden waste water to land. Removal of phenolics equaled or exceeded 99% at all soil depths from 1 to 4 ft. Both degradation and sorption were responsible for the observed removal efficiency. Based on this study, it is anticipated that the effects of these organics in the soil medium will be limited to the treatment zone.

6.5.4 Environmental Effects

Phenolics and polycyclic aromatic hydrocarbons, when applied at high concentrations, will result in the sterilization of soils (72). At low concentrations (0.01 to 0.1% of soil, by weight), phenolics serve as an available substrate. As the level is increased (0.1 to 1.0% of soil, by weight), an increasingly strong inhibitory or sterilizing effect occurs. At these levels, there is a marked decrease in microbial numbers, but not a complete die-off. After a period of time, microbes adapt or phenol is lost through sorptive inactivation or volatilization, and a regrowth of population occurs.

The sterilization of soils by phenol is due to the inhibition of microbial enzyme activity (91), particular urease and catalase. Effects of other phenolics and PAH compounds could not be found in the literature, but it is suspected that these compounds also affect essential enzyme activity.

The toxicity of heavy metals in soils is well documented (54). However, the concentrations of arsenic, copper, chromium, nickel and zinc at which soils are affected are extremely high. If application rates are relatively low, it will take years for the sorption capacity in soil to be exhausted, even with low CEC soils. However, the chemistry of metals in soils and synergistic effects is quite complex and difficult to predict. Therefore, a carefully monitored application program is imperative.

7.5.5 Conclusion

Toxic organic compounds in wood preserving wastes are easily degraded by microbes which are common in soil. In addition, other mechanisms such as volatilization and photodecomposition will readily eliminate these constituents. Sorption by soils will result in the immobilizaton of both organics and heavy metals. The heavy metal concentrations should not present a problem in neutral pH (>6) soils.

Therefore, this hazardous waste appears to be suitable for land application as a treatment alternative.

7. CONCLUSIONS

7.1 General

Examination of wastes that have been land-applied has suggested a series of conclusions.

The range of waste types that may be treated by land application is quite broad. Heavy metal and toxic material content are much less restrictive than would be expected from municipal landfill experience. However, there are some caveats:

- It must be accepted that the disposal site has acquired properties that will impair it for some future uses, and as with any disposal site, future land use is restricted. The extent of the use restrictions has not yet been determined.

- Site-specific and climate-specific restrictions are much more significant than is the case with other disposal means.

- Land application as a waste treatment is a multi-disciplinary process. While the operatons carried out are simple and not "high-technology", the concepts are complex.

- It is a longer-duration process than other disposal techniques, and operating parameters must be closely monitored or controlled. Knowledgeability in soil sciences, and cultivation skills more common to agricultural practice than to conventional disposal operations, are required. Until these are acquired operations will be hampered.

While both economic and environmental performance factors have been favourable for those wastes that have been treated in this way, documented results on land application practices for industrial wastes are sparse. No data is available on, for example, the metal concentration in the soil that begins to affect biological activity or begins to exceed the soil's binding capacity. There is a requirement for considerable development work research on waste destruction efficiency as a function of climate, soil characteristics and waste composition and on maximum tolerable loadings of contaminant (per application and cumulative).

7.2 Principles and Science

7.2.1 Land Use

The use of soil as a disposal medium or mechanism will almost inevitably result in effects on the soil. The site will generally be contaminated with quantities of indestructible contaminants that render it unfit for many uses, particularly agricultural or playground - recreational. (Of course, landfilling, solidification, disposal of incinerator residue, and sewage treatment also consume land.) The contaminant is in general dispersed in the top 15 cm to 25 cm of soil, in an oxidized or precipitated state, adsorbed on soil organic or mineral materials. It is susceptible to mechanical displacement by water runoff, or possibly solubilization in the case of some incident seriously acidifying the site.

During waste application and cultivation, airborne dust may be carried from the site. In general, however, waste treatment by land application has not been accompanied by major dispersion off-site of persistent materials.

7.2.2 Volume

Superficially, land use per tonne waste by land application appears to be much greater than for landfilling. A land application operation distributes waste in the top 15 cm to 25 cm of the soil over a large area, while a landfill is much deeper and can accommodate the same volume in much less area.

However, wastes most amenable to land application have been aqueous sludges, with organic and some metallic components. The effect of land application has been to eliminate the water component by evaporation or percolation, biodegrade the organic component, and sorb the metallic components in the soil. This, in the case of waste water treatment sludges, has resulted in major reductions in the volume of waste accumulated in the soil. When, for example, 95% of the volume of a waste is either water or biodegradable, land application of the waste would in the long run become much more space-efficient. This contributes to the frequent cost advantage of land application.

This advantage is most apparent where the site is close to the generation site, so that transportation costs are low.

7.2.3 Degradation Conditions

Land application is conducted under aerobic, oxidizing conditions, at neutral pH. This in most cases results in oxidation of organic compounds to carbon dioxide and water, and formation of metal oxides, hydroxides, carbonates, etc. The latter compounds tend to be relatively insoluble in water, so

that metallic contaminants will precipitate from solution. Also, humic materials and clay minerals tend to adsorb metals in these forms. The net effect is one of conversion of organics to innocuous volatiles, and fixation of inorganics.

By contrast, a landfill is generally at some time anaerobic. Biological activity takes place under reducing conditions, and in the process organic acids are often formed. As a result, metals are solubilized and mobilized, and leaching of both BOD and metal species can readily occur. From this standpoint, there are some long-term security advantages to land application as compared to the landfill-storage approach to waste disposal.

7.2.4 Contaminant Loading

Quantities of waste per application generally have been determined on a case-by-case basis. The waste layer must be thin enough to be readily mixed (after drying) with the soil, so that aerobic conditions apply.

Much less is known about the total concentration of contaminants that may be added to the soil in a landfarm. There is no reported data on the maximum levels of toxic metals that can be applied before interference with biodegration occurs. Presumably this would be a function of pH, redox potential, soil characteristics, and the solubility/availability characteristics of the metal under site conditions. The lack of specific knowledge in this area poses a significant barrier to the practice of land application of wastes; it will be necessary to adopt conservative contaminant loadings at land application sites until immobilization performance is verified at higher loads.

7.2.5 Site Factors

The characteristics of the site are the most important determinants of the viability of a potential land application operation. The most obvious characteristic is climate. Where the growing days in a season are fewer, degradation will occur at a proportionally lower rate, and a greater land area will be required to degrade wastes to an acceptable level in a given time. Site sizing will depend strongly on this. In some cases it could be a limiting factor.

Rainfall will affect the land application process as well. An area of high rainfall will require site designs that make provision for more runoff and/or leachate than in an arid area. In addition, a rainy climate causes difficulty in waste application; it is not practical to apply or cultivate waste when the soil is very wet, because of reduced equipment mobility and the greater difficulty in maintaining the soil in an aerobic state. Serious limitations in site use are imposed in a rainy period.

7.2.6 Environmental Impacts

Specific impacts will depend on the waste being disposed. Leachate and runoff potential and their control have been described. Other effects to be considered are air emissions, noise and traffic. Air emissions may include dust during the cultivating stages of the process; the dust is said to be less than is normal in agriculture (54), but will occur throughout the season (as often as biweekly) rather than during the planting season only. Odour will be dependent on the waste being farmed; under good practice, no septic odour should result. Oily wastes may have some odour.

Noise will arise from application and cultivation activities. Levels would not be dissimilar to that in a farming operation. Traffic would be significantly higher where spreading is done by vacuum truck; during the spreading period, possibly comparable to that in the vicinity of a landfill site.

8. RECOMMENDATIONS

Recommendations can be subdivided into the general, which apply to land application of hazardous or non-hazardous wastes, and those specific to hazardous wastes. The general provisions have been laid dows in previous works on sewage, sludge and oily wastes, and are outlined by U.S. EPA (54), Ontario Ministries of the Environment and Agriculture and Food (50), and Alberta Environment (51), which have been referred to above. They contain recommendations on siting, for distance to watercourses and habitations, and terrain. Operating variables discussed are site slope versus soil type, recommended waste application rates, dewatering of sludge and underdrainage, and the principles involved apply equally to hazardous wastes. However, there are some recommendations, both general and specific, that are applicable particularly to hazardous wastes land application. These are:

a) Hazardous wastes should not be treated by land application unless permanent restrictions are placed on post-closure use of the land.

b) Volatile hazardous materials are not suited for land application, and wastes containing them in significant quantities should not be treated in this way. Where a waste degrades to volatile hazardous components, it must be determined that these will not be present in significant quantities.

c) Non-degradable wastes that cannot be safely immobilized by soil should not be treated by land application.

d) Biocidal materials (e.g. arsenites) with potential for interfering with biodegradation processes at application concentrations should not be treated by land application.

e) Soil pH should be maintained above 6.5.

f) Extremely high or low pH wastes should not be land applied, as they may mobilize metallic contaminants.

g) Nitrogen addition should be considered where the C:N ratio is > 35:1.

h) The slope of the site should not exceed 6% to prevent waste flow under wet conditions.

i) Before any land application project is begun, pilot scale field tests must be done, to determine if the waste is suitable.

9. FUTURE RESEARCH NEEDS

Degradation of organics and fixation of inorganics can provide a secure and durable disposal facility for many wastes that would otherwise be expensive or problematical to dispose of. However, specific information is lacking relative to wastes of different composition, and in different soil and climatic conditions. Some areas where additional research is required are;

- long-term contaminant loading that produces toxic effects to soil micro-organisms.

- biodegradation rates for specific waste streams under varying climatic and soil conditions;

- changes in the characteristics of the soil with continued waste application; site life expectancy with various wastes;

- migration of contaminants at various stages of waste degradation and site life span.

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APPENDICES

APPENDIX 1
HAZARDOUS WASTE INVENTORY REPORT
NEWFOUNDLAND AND LABRADOR, EPS ATLANTIC REGION, 1983

Selected establishments were surveyed to quantify their waste generation, and waste-per-employee. The results were extrapolated to each industry on the basis of the waste-per-employee factor. Mining, manufacturing, non-manufacturing and institutional establishments were included. The waste types considered in the study were:

1. Acid Solution
2. Alkali Solution
3. Pesticides, Herbicides, and Biocides
4. Paint Sludges
5. Solvents
6. Tetraethyl Lead Sludges
7. Chemical Toilet Wastes
8. Tank Bottom Sediments
9. Oil: Waste or Contaminated
10. Drilling Muds
11. Contaminated Soil and Sand
12. Food Processing Wastes
13. Latex Waste
14. "Restricted" Waste
15. Miscellaneous

Amounts of each found in the four industry sectors investigated are summarized in the following tables.

ESTIMATED WASTE QUANTITIES BY TYPE GENERATED BY THE MINING INDUSTRIES (FIGURES ARE IN TONNES/YEAR)

SIC GROUP	WASTE TYPE				
	ACIDS	SOLVENTS	WASTE OIL	MISCELLANEOUS	TOTAL
0500 Metal Mines	4	158	1,538	25	1,725
0700 Non-Metal Mines	-	3	617	-	620
0800 Quarries	-	7	29	-	36
0900 Mining Services	-	-	163	-	163
TOTAL	4	168	2,347	25	2,544

ESTIMATED WASTE QUANTITIES BY TYPE GENERATED BY THE MANUFACTURING INDUSTRIES (FIGURES ARE IN TONNES/YEAR)

	WASTE TYPE											
SIC GROUP	ACID	ALKALI	PESTICIDE HERBICIDE BIOCIDE	PAINT SLUDGE	SOLVENT	TETRAETHYL LEAD SLUDGE	TANK BOTTOM SEDIMENT	WASTE OIL	CONTAM. SOIL & SAND	LATEX	MISCL.	TOTAL
1700 Leather	-	-	-	-	-	-	-	-	-	-	-	-
1800 Textile	<1	<1	-	-	<1	-	-	-	-	-	-	1
2500 Wood	-	-	10	-	<1	-	-	3	-	9	-	22
2600 Furniture	-	-	-	1	4	-	-	-	-	-	-	5
2700 Paper	-	-	15	-	13	-	14	11	-	-	-	53
2800 Printing	-	-	-	-	4	-	-	-	-	-	13	17
2900 Primary Metal	2	4	-	-	-	-	-	95	-	-	-	101
3000 Metal Fabric	-	<1	-	-	2	-	-	2	11	-	-	15
3200 Transport Equipment	-	-	-	-	1	-	1	-	-	<1	-	2
3600 Petroleum	-	-	-	-	-	<1	25	-	-	-	-	25
3700 Chemical	-	2,000	-	11	3	-	1,853	4	-	-	1	3,871
TOTAL	2	2,004	25	12	27	<1	1,893	20	106	9	13	4,112

ESTIMATED WASTE QUANTITIES BY TYPE GENERATED BY NON-MANUFACTURING INDUSTRIES (FIGURES ARE IN TONNES/YR)

	WASTE TYPES					
SIC GROUP	ACIDS	ALKALI	PESTICIDE HERBICIDE BIOCIDE	SOLVENT	WASTE OIL	TOTAL
Transportation	-	1	-	3	71	75
Utilities	124	114	9	-	-	247
TOTAL	124	115	9	3	71	322

ESTIMATED WASTE QUANTITIES BY TYPE GENERATED BY NON-MANUFACTURING INDUSTRIES (FIGURES ARE IN TONNES/YR)

	WASTE TYPES					
SIC GROUP	ACIDS	ALKALI	PESTICIDE HERBICIDE BIOCIDE	SOLVENT	WASTE OIL	TOTAL
Transportation	-	1	-	3	71	75
Utilities	124	114	9	-	-	247
TOTAL	124	115	9	3	71	322

ESTIMATED WASTE QUANTITIES BY TYPE GENERATED BY INSTITUTIONS (FIGURES ARE IN TONNES/YR)

SIC GROUP	WASTE TYPE					
	ACIDS	ALKALI	SOLVENTS	WASTE OIL	MISCELLANEOUS*	TOTAL
8000 Universities	<1	<1	3	-	-	4
8200 Hospitals	-	-	13	<1	230	243
TOTAL	<1	<1	16	<1	230	247

* Primarily photographic developer.

APPENDIX 2
HAZARDOUS WASTE IN NEW BRUNSWICK
ENVIRONMENT NEW BRUNSWICK, 1982

Three inventories of hazardous waste have been compiled for New Brunswick, the first in 1975 by Environment New Brunswick, the second in 1978 by Environment Canada (EPS) and the third in 1982, again by Environment New Brunswick to refine the data. All three were conducted by surveying industry. For the latest, most refined, companies were selected from the directory, "New Brunswick Manufacturers and Products, 1981", from SIC groups that probably would generate hazardous wastes. A representative sample was selected. The survey also included hospitals, universities, scrap yards, dry cleaners and film developers. Questionnaires were filled by company visits or telephone interviews.

From the waste-per-employee ratios for the companies in the sample, the survey results were extrapolated to each industry. They are shown in summary on the attached table.

The inventory deals with current disposal methods for the wastes generated; however, those discussed are the ones considered "hazardous" by Environment New Brunswick, and little emphasis is placed on those appropriate for landfarming.

CROSS REFERENCE BETWEEN MAJOR STANDARD INDUSTRIAL CLASSIFICATION (SIC) GROUPS AND QUANTITY (KG/YR) AND TYPE OF HAZARDOUS WASTE FOUND IN NEW BRUNSWICK

WASTE GENERATOR	PHOTO-GRAPHIC CHEMICALS	RADIO-ACTIVE WASTE	SOLVENTS	ORGANIC SLUDGE	PAINT SLUDGE	ACID SOLUTIONS	CLEANING SOLUTIONS	PCB CONTA-MINATED WASTE	TOXIC CHEMICALS	ALKALINE SOLUTIONS	LABORA-TORY CHEMICALS	PESTICIDES	TOTAL
Food and Beverage Industries						1,136				3,343			4,479
Rubber and Plastics Products Industries			7,809	204									8,073
Leather Industries													
Textile Industries													
Knitting Mills													
Clothing Industries			12										12
Wood Industries			479	45,449	265	818							47,011
Furniture and Fixture Industries			6,757		2,513								9,270
Paper and Allied Industries			10,614	2,584				1,000					14,198
Printing, Publishing and Allied Industries	53,520		1,102	694		229							55,545
Primary Metal Industries						17,000							17,000
Metal Fabricating Industries (except machinery and transportation industries)		139,000	10,030			10,943	22,441		8,545	910			191,869
Machinery Industries (except electrical machinery)			10,079		9,179		1,908						21,166
Transportation Equipment Industries			14,800		11,818					3,000			29,618
Electric Products Industries	272		1,113		105	2,578				108			4,176
Non-Metallic Mineral Products Industries			18,404		3,717	3,931							26,052
Petroleum and Coal Products Industries			3,048										3,048
Chemical and Chemical Products Industries			1,265	91	15,260	18				32		10	16,676
Miscellaneous Manufacturing Industries			4,072							400			4,472
Hospitals and Universities	546,577		16,161	4	3,873	950				154	756		568,475

CROSS REFERENCE BETWEEN MAJOR STANDARD INDUSTRIAL CLASSIFICATION (SIC) GROUPS
AND QUANTITY (KG/YR) AND TYPE OF HAZARDOUS WASTE FOUND IN NEW BRUNSWICK

WASTE GENERATOR	PHOTO-GRAPHIC CHEMICALS	RADIO-ACTIVE WASTE	SOLVENTS	ORGANIC SLUDGE	PAINT SLUDGE	ACID SOLUTIONS	CLEANING SOLUTIONS	PCB CONTA-MINATED WASTE	TOXIC CHEMICALS	ALKALINE SOLUTIONS	LABORA-TORY CHEMICALS	PESTICIDES	TOTAL
Film Laboratories	114,331												114,331
Power Generation								16,000					16,000
Scrap Yards													
Dry Cleaners													
Other				79		164				272			515
TOTAL	714,700	139,000	105,745	49,165	46,730	37,767	24,349	17,000	8,545	8,219	756	10	1,151,986

Not included in the laboratory chemicals category is 180 copies/yr of radioactive wastes.
Not included in the above Table is 184,852 kg of chemical spills.

APPENDIX 3
FACILITIES DEVELOPMENT PROCESS PHASE 2
ONTARIO WASTE MANAGEMENT CORPORATION, 1983

Developed for the Ontario Waste Management Corporation, this inventory of hazardous wastes is intended as a tool in planning for future waste disposal facility needs. The inventory is basically a theoretical one, with a back-up of interviews with selected companies. All waste streams are estimated, based on waste-per-employee figures from the literature for each SIC class. This has resulted in some overestimation in totaling wastes; for instance, both a waste and the sludge from its treatment could be included although actually only one would exist. Wastes disposed or recovered on-site are included in the total as well. The OWMC waste classification system is directed toward treatment options suited to each stream rather than industrial source. A summary of the inventory is shown in the following Table.

ESTIMATED WASTE GENERATED BY INDUSTRY TYPE
(TONNES X 1000)

INDUSTRY / WASTE CATEGORY	ORGANIC SLUDGES & STILL BOTTOMS	SOLVENTS & ORGANIC SOLUTIONS	OILS & GREASES	OIL/WATER MIXTURES	ORGANIC & OILY RESIDUALS	HEAVY METAL SOLUTIONS & RESIDUALS	MISCL. CHEMICALS & PRODUCTS	PAINTS & ORGANIC RESIDUALS	AQUEOUS SOLUTIONS WITH ORGANICS	ANION COMPLEXES	SLUDGES & INORGANIC RESIDUALS	PESTICIDES & HERBICIDE WASTES	PCB WASTES	CLEANUP RESIDUALS	TOTAL TONNES X 1000	TOTAL %
Primary Metal Industries	+	0.9	3.2	2.9	182.7	278.7	56.6	2.1	-	26.3	233.3	-	-	266.7	766.7	51.5
Chemical Industries	11.9	6.2	6.0	3.9	2.8	68.2	27.0	8.5	0.7	3.2	5.2	0.5	-	2.8	146.9	9.9
Fabricated Metal Products	0.2	1.2	1.7	4.7	1.5	101.2	+	9.5	-	4.2	1.0	-	-	-	125.2	8.4
Machinery Except Electrical	0.5	10.7	1.7	48.5	12.6	28.0	0.7	3.2	-	-	0.2	-	+	0.1	106.2	7.1
Paper Products	-	2.3	0.4	-	-	4.5	72.8	2.7	-	-	-	-	-	-	82.7	5.5
Transportation Equipment	28.1	0.5	6.7	2.1	0.7	32.6	0.4	11.3	-	-	0.5	-	-	-	82.6	5.5
Petroleum	0.5	0.6	29.0	+	9.9	19.4	+	1.5	+	-	1.5	-	+	0.3	62.8	4.2
Printing	-	2.1	0.4	0.8	0.2	13.9	2.8	+	-	-	-	-	-	0.3	20.5	1.4
Stone, Glass, Concrete	-	8.3	+	0.3	0.1	6.5	-	0.9	-	-	3.4	-	-	-	19.5	1.3
Electrical Machinery	0.1	0.3	0.9	5.6	1.4	6.7	0.2	0.5	-	0.7	0.2	-	+	+	16.2	1.1
Rubber & Plastics	2.9	3.4	0.6	+	0.7	1.1	0.1	0.5	-	-	1.3	-	-	2.1	12.7	0.9
Non-building Construction	-	-	0.1	-	8.7	-	-	-	-	-	-	-	-	-	8.9	0.6
Misc. Manufacturing	+	0.8	+	-	-	4.6	0.1	1.9	-	0.4	-	-	-	-	7.8	0.5
Food Products	0.8	1.6	0.2	-	+	0.8	4.2	-	-	-	+	-	-	-	7.7	0.5
Furniture	-	0.1	0.1	-	-	1.2	+	4.8	-	-	-	-	-	-	6.2	0.4
Measuring Instruments	0.6	1.2	0.2	+	+	2.4	+	0.6	-	-	0.1	-	-	-	5.2	0.3
Leather Products	1.0	+	-	-	-	1.9	-	-	-	-	0.1	-	-	-	3.0	0.2
Textiles	0.2	0.9	0.2	+	+	+	-	+	-	-	-	-	-	-	1.4	0.1
Lumber & Wood	-	0.4	+	-	+	0.7	+	0.1	-	-	-	0.1	-	-	1.4	0.1
Apparel	-	0.4	-	-	-	-	-	-	-	-	-	-	-	-	0.4	0.1
Hospitals	-	-	-	-	-	-	-	-	-	-	-	-	-	2.0	2.0	0.1
Other	-	0.2	+	+	+	1.9	+	1.9	-	-	-	-	+	-	4.1	0.3
TOTAL	47.1	42.1	51.0	69.0	221.4	574.3	144.7	50.0	0.7	34.8	246.8	0.6	0.2*	7.6	1490.3	100.0

+ Waste quantities less than 100 tonnes
* PCB's not included in SIC total

Note: Totals may not add due to rounding.

APPENDIX 4
HAZARDOUS WASTE IN NORTHERN AND WESTERN CANADA
REID, CROWTHER AND PARTNERS LIMITED, 1980

This inventory was conducted as part ot "Feasibility Study for Hazardous Waste Management in Northern and Western Canada." Major objectives of the study were stated to be:

- To determine the feasibility... of managing the hazardous wastes in the study area.

- To propose alternative designs of systems... to manage these wastes....

- To provide (and compare)... cost estimates for each... system...

- To provide cost estimates for the transportation... to the facilities.

- To provide a generalized description of the potential of an environmental impact of each... system.

- To identify and recommend... facility location and an implementation program.

The theoretical approach was used in preparing this inventory. Waste generation-per-production-employee rates were obtained from literature and applied to industries in the Northern and Western Region. Both waste type and amount were estimated this way. A major emphasis in the inventory is said to be to classify wastes in a way that will facilitate

decisions on their treatment and disposal. To this end wastes are grouped in 40 categories by type, and these 40 categories are discussed in terms of treatment requirements. The figures "represent those hazardous wastes that would be available to a disposal facility", and do not include "non- hazardous wastes", contaminated soils and wastes currently treated successfully.

It is noted in the text that an accuracy of ±25% is not feasbile. Total quantities for the region, and a breakdown by "management class" are shown in the following table.

WASTE GENERATION SUMMARY

WASTE CATEGORY	NW ONTARIO (tonnes)	MANITOBA (tonnes)	SASKATOON (tonnes)	ALBERTA (tonnes)	BC (tonnes)	YUKON (tonnes)	NWT (tonnes)	NW CANADA (tonnes)
1. PCB	neg	10	neg	10	10	neg	neg	30
2. Oils	3,500	9,500	12,500	20,000	23,000	neg	neg	68,500
3. Halogenated Solvents	N/A	700	200	900	2,100	neg	neg	3,900
4. Nonhalogenated Solvents	400	100	20	5,600	700	neg	neg	6,820
5. Heavy Metal Solvents	neg	10	neg	neg	20	neg	neg	30
6. General Mixed Metal Bearing Sludge	100	600	500	5,000	2,400	neg	neg	9,600
7. Lead Sludge	neg	neg	neg	neg	neg	0	0	neg
8. Chromium	0	500	60	100	60	0	0	720
9. Copper	0	neg	neg	neg	neg	0	0	neg
10. Aluminum	neg	40	neg	70	30	0	0	140
11. Magnesium	0	neg	0	0	0	0	0	0
12. Pesticides	0	neg	50	180	80	0	0	310
13. Textile Waste Treatment	0	10	10	10	40	0	0	70
14. Ink	N/A	10	neg	10	40	0	0	60
15. Organic Tannery Waste	0	9,600	102,800	2,100	1,000	0	0	25,000
16. Dust and Scrubber	0	20	30	90	100	0	0	140
17. Paint	neg	300	80	300	700	neg	neg	1,380
18. General Mixed Aqueous Metal Bearing Sludge	neg	neg	neg	50	30	neg	0	80
19. Acids with Heavy Metals	neg	500	40	500	500	neg	neg	1,540
20. Acids	10	900	2,200	23,700	14,100	neg	neg	50,910
21. Alkalis with Heavy Metals	0	50	10	70	40	neg	neg	170
22. Alkalis	10	2,200	3,600	5,500	5,200	neg	neg	16,510
23. Plastics, Resins and Latex	10	200	240	460	800	neg	neg	1,710
24. Phenols	neg	20	neg	60	50	neg	neg	130
25. Cyanides	neg	600	70	1,200	560	neg	neg	2,430
26. Phosphate Sludge	0	20	neg	10	20	0	0	50
27. Explosives	0	0	0	neg	neg	0	0	neg
28. Contaminated Containers and Equipment	10	20	10	460	400	neg	0	910
29. Contaminated Soil and Sand	10	1,800	400	2,500	2,500	neg	neg	11,010
30. Asbestos	neg	10	10	3,700	100	0	0	3,820
31. Ammonia	neg	neg	neg	10	10	0	0	20
32. Scrap Batteries	0	30	0	10	20	0	0	60
33. Waste Activated Carbon	neg	100	neg	40	100	0	0	240
34. Infectious Waste	200	900	930	1,200	N/A	neg	0	3,240
35. Tank Bottoms	40	500	720	1,300	1,200	neg	neg	3,760
36. Chemicals	neg	5,500	9,400	12,200	12,500	neg	neg	39,600
37. Sulphur	neg	80	120	200	20	0	0	420
38. Fly Ash	neg	300	20	150	300	neg	neg	770
39. Photo Chemicals	120	1,300	1,800	1,100	1,100	neg	neg	4,420
40. Spent Catalyst	neg	neg	neg	neg	neg	neg	neg	neg
TOTAL	4,400	37,000	46,000	89,000	70,000	neg	neg	246,400

N/A = Not Available
neg. = Negligible Amount: less than 10 tonnes

APPENDIX 5
INVENTORY OF HAZARDOUS WASTE IN THE NORTHWEST REGION
W.L. WARDROP AND ASSOCIATES LIMITED, 1979

This inventory, completed January 1979, was "commissioned to determine the nature and magnitude of the problem in quantitative terms... to determine the types and quantities of hazardous waste... to specify the locations... and to identify current transportation and disposal practices". It was conducted by the survey method; questionnaires were sent to 8,475 establishments - 19.6% responded, representing 29.4% of employment at those establishments. The waste volumes were extrapolated (within each industry) using the waste-per-employee factor calculated from the report data.

A notable aspect of this inventory is the preponderant effect of the mining industry on waste amounts; about 90% of alkaline and acid wastes come from this source. Similarly, drilling mud volumes are prominent. Major portions of the "Solid Chemical Wastes" discussed are not amenable to treatment. This includes 800 million lbs./yr. of power utility fly ash; 6.5 million lbs./yr. of impure arsenic trioxide from mining operations; 4.98 billion lbs./yr. of sulphur and spent alumina from oil and gas processing and extraction. By contrast, the orientation of the "Hazardous Wastes in Northern and Western Canada" inventory, did not require inclusion of mining, drilling or power plant wastes. This illustrates the point that interpretation of the values in an inventory must consider the original purposes and scope of the inventory. The values obtained are summarized in the following table taken from the report.

SUMMARY OF INVENTORY RESULTS BY WASTE CATEGORY

WASTE	REPORTED VOLUME	PROJECTED VOLUME*	VOLUME FOR TREATMENT
Acid Solutions	12,000,000	26,000,000	45,000
Alkaline Solutions	13,000,000	103,000,000	130,000
Contaminated Soil and Sand	126,000,000	3,000,000,000	12,600
Drilling Mud	170,000	6,300,000	-
Oily Wastes	126,000	2,000,000	63,000
Paint Sludges	3,800	4,400	-
Pathological	Solid 120 Liquid 2,000	120 2,000	135 2,300
Solvents	3,900	27,000	21,000
Oil/Solvent Mix	1,500	22,000	22,000
Pesticides	140,000	140,000	450
Tank Bottom Sediment	1,800	8,000	45
Tetraethyl Lead Sludges	14	190	190
Aqueous Chemical Wastes	12,000,000	140,000,000	23,000
Oil-Based Chemical Wastes	450	2,300	2,300
Solid Chemical Wastes	500,000	2,700,000	40
Heavy Metal Wastes	68,000	-	-
Aqueous Electrolyte	2,400,000	14,000,000	-
Photographic Wastes	500	4,500	4,500
Ink Wastes	360	450	450
PCB	7	23	23
	166,308,451	3,294,210,983	327,033

* Reported volume plus extrapolated estimate for non-respondent firms.

APPENDIX 6
CHEMICAL WASTE INVENTORY REPORT
M.M. DILLON LIMITED, 1982

A survey method study, this inventory was compiled from the responses of some 418 establishments in Saskatchewan. Total waste volumes were estimated by using the employee-waste generation factor obtained from responses. In this case, the thrust of the inventory was to produce estimates of volumes suited to various disposal means at centralized facilities. Where wastes were not amenable to centralized disposal - e.g. brine wastes from potash mining, fly ash, municipal water treatment sludge - the wastes' volumes were not included in the body of the report (but were appended). Where wastes were suited for municipal sewage as well as centralized treatment, (e.g. recovery) such options were discussed.

The survey covered SIC classes from 001 (experimental farms) to 9510 (local administration).

This resulted in numerous waste streams being reported for "service" establishments - dry-cleaning, photo processing, education, vehicle repair. The streams tend to be small, varied and untreated.

The inventory uses a classification system based on the "Transportation of Dangerous Goods Act" listing of dangerous waste streams, with additional classes reflecting local industrial conditions - a total of 20 classes, with sub-classifications. Although the list of industries surveyed is comprehensive, the list of waste reported is not. Food processing wastes and other wastes that are landfilled or "land disposed" on site may not be included. This may be

because such wastes have not been perceived as "hazardous" in the Province of Saskatchewan, or it may reflect the legislative or enforcement environment with regard to wastes. A group of wastes suited for "land disposal" is noted; land disposal including techniques such as landfilling, land spreading and deep well injection.

A summary of the inventory results is shown in the following table.

REPORTED AND ESTIMATED CHEMICAL AND INDUSTRIAL WASTE QUANTITIES BY WASTE CLASSIFICATIONS

Waste Type	Rep. Qty.	Est. Qty.
WASTE OIL	2945.7	3762.
TOTAL	2945.7	3762.
OILY WASTES	0.650	0.65
• Crude tank bottoms	10.	15.
• Asphalt emulsions	6.275	7.22
• Oil and water	417.73	642.
• Hydrocarbon condensate	24.965	43.4
• Oily sludge	245.04	635.
• Slop oil	3.4	3.4
• Waste vegetable oil	1.6	2.13
TOTAL	709.66	1349.
PLANT AND ANIMAL WASTES		
• Fats	435.3	869.
• Wood sugars, fibres & grit	6.8	6.8
TOTAL	442.1	876
ACIDS	1.252	57.6
TOTAL	1.252	57.6
PICKLE LIQUOR	11.0	16.5
TOTAL	11.0	16.5
ALKALIS	.6	.9
• Spent caustic	2686.7	4036.
• Lime sludge	4820.	6723.
• Metal cleaners	1449.41	1461.
• Amine and ammonia waste	12.91	19.4
TOTAL	8969.62	12240.
SPENT CATALYST WASTE	160.0	240.
TOTAL	160.0	240.
METAL SLUDGES	4.504	9.38
TOTAL	4.504	9.38

Waste Type	Rep. Qty.	Est. Qty.
ORGANIC SOLVENTS	167.93	352.
TOTAL	167.93	352.
CHLORINATED SOLVENTS	14.9	18.4
TOTAL	14.9	18.4
PLASTIC RESINS	27.3	47.6
TOTAL	27.3	47.6
PAINT AND PIGMENTS		
• Paint and ink sludge	16.855	53.9
• Paint residue (solid)	5.7	9.65
TOTAL	22.555	63.6
PHOTOCHEMICALS	27.564	45.1
TOTAL	27.564	45.1
WOOD PRESERVING WASTES		
• Copper cadmium arsenate	u/s	u/s
PCB's	97.2	98.8
TOTAL	97.2	98.8
PESTICIDES	14.622	17.0
TOTAL	14.622	17.0
HERBICIDES	0.206	0.324
TOTAL	0.206	0.324
PHENOLS (including pentachlorophenol)	0.60	0.9
TOTAL	0.60	0.9
SOLID WASTES, N.O.S.	.006	.006
• Contaminated soil	18.2	80.9
• Scrubber dust	3000.0	3000.0
TOTAL	3018.2	3081.
ASBESTOS	4.0	4.0
TOTAL	4.0	4.0
HOSPITAL WASTES	.5	88.5
TOTAL	.5	88.5
TOTAL	16640.	22367.

Notes:
Quantities in tonnes/year.
u/s - Unspecified.
N.O.S. - Not Otherwise Specified.

OTHER REPORTED WASTE STREAMS

Waste Type	Reported
BRINE WASTES	9067000
WATERWORKS AND SOFTENING SLUDGE	1800
AGRICULTURAL CHEMICALS	
• Chemical containers & residues	4

Waste Type	Reported
FLY ASH	700000
MERCURY-CONTAMINATED WASTE	1000000
SLAG	70000

APPENDIX 7
INVENTORY OF WASTE OIL IN SASKATCHEWAN
THE CAMBRIAN ENGINEERING GROUP, 1979

Done by the survey method, this inventory covers waste hydraulic and lubricating oil, including cutting oils, generated annually in Saskatchewan. Industrial process and electrical insulating oils were not included. A primary purpose is to identify the sources of waste oil and its disposal from those sources, so that the potential for recycling or reuse may be assessed. The results are summarized in the following table.

A noteworthy feature of the inventory is the dispersion of the waste oil. Much of it is produced in agriculture and individual consumer use. Although the volumes produced are impressively large, the availability for centralized disposal is low due to the multiplicity of small users. Rather than a problem in treatment of disposal, waste oil appears to present a problem in economically assembling the waste for treatment and, secondarily, in marketing the recovered product.

It may be noted that, in smaller centres especially, "spread on land is a primary route for disposal of waste oil (see Table). The degree of security of this "spreading" in unstated. However, metals in waste oils have been cited as sources of water contamination.

TOTAL WASTE OIL VOLUMES (IMPERIAL GALLON/YEAR)
BY DISPOSITION AND POPULATION CENTRES

	METHOD OF COLLECTION		METHOD OF ULTIMATE DISPOSAL								
	COMMERCIAL PICK-UP	MUNICIPAL PICK-UP	LANDFILL	BURN AS WASTE	SPREAD ON ROADS	SPREAD ON LAND	FARM USE	GARBAGE	BURN AS FUEL	OTHER	ULTIMATE
Cities over 100,000	1,825,050	43,395	779,227	36,465	1,157,402	42,567	6,007	317,419	10,850	26,263	2,376,270
Towns of Population 10,000 - 99,999	327,318	29,568	208,996	5,712	419,091	23,752	23,653	10,094	-	13,872	705,170
Towns of Population 1,000 - 9,999	-	275,010	554,121	35,375	45,973	1,696	28,834	1,212	3,320	30,231	700,762
Towns of Population less than 1,000 and Rural Municipalities	-	-	558,486	1,580,760	593,600	296,335	478,702	338,130	11,396	3,801	3,861,210
TOTAL	2,152,368	347,973	2,100,830	1,658,312	2,216,066	364,350	537,266	666,855	25,566	74,167	7,643,412

Note: An additional 315,000 imperial gallon per year volume of commercially collected waste oil was identified as being re-refined.

TOTAL WASTE OIL VOLUMES
BY MAIN USE SECTORS AND POPULATION CENTRES

	AUTOMOBILE SALES AND SERVICING	DO IT YOURSELF AUTOMOBILE SERVICE	TRANSPORTATION	MANUFACTURING INDUSTRY	PRIMARY INDUSTRY	AGRICULTURE	GOVERNMENT	OTHER	TOTAL
Cities over 100,000	922,894	372,396	934,508	59,498	25,125	155,176	183,152	38,521	2,691,270
Towns of Population 10,000 - 99,999	195,815	78,999	69,419	16,489	2,263	144,012	81,303	116,870	705,170
Towns of Population 1,000 - 9,999	353,721	142,728	116,130	1,782	25,717	7,572	28,120	24,992	700,762
Towns of Population less than 1,000 and Rural Municipalities	148,557	59,942	0	0	58,625	3,594,086	0	0	3,861,210
TOTAL	1,620,987	654,065	1,120,057	77,769	111,730	3,900,846	292,575	180,383	7,958,412

Note: An additional 315,000 imperial gallon per year volume of commercially collected waste oil was identified as being re-refined.

APPENDIX 8
CANADIAN NATIONAL INVENTORY OF HAZARDOUS AND TOXIC WASTES
GORE AND STORRIE LIMITED, 1982

This inventory, national in scope, relied on the theoretical approach.

A master list of hazardous and toxic wastes was established for each SIC number. U.S. waste stream experience, derived from United States EPA work, was used as a basis. Waste generation factors for Canada, based on SIC number, employees and sales/production volumes, were calculated.

These factors were applied to produce Canadian values. "Localizing" was based on comprehensive industry distribution and location data obtained from a survey organization.

The total waste for Canada was estimated to be 3,280,863 tons wet weight, or 1,300,000 tons dry.

The inventory in its final form aggregated producers into these SIC groups: 28, 33 and 34, and "others". Regional totals were compiled using this aggregation.

REGIONAL TOTALS

	SIC 28	SIC 33 AND 34	OTHER	TOTAL
Atlantic	89,225	35,051	50,591	174,867
Quebec	575,460	237,949	138,508	951,917
Ontario	687,272	766,276	151,559	1,605,107
West & North	138,437	69,868	67,241	275,546
Pacific & Yukon	45,404	147,956	80,066	273,426
				3,280,863

In contrast to the other inventories investigated, this may be considered an inventory of waste generators.

APPENDIX 9
HAZARDOUS WASTE GENERATION AND OFF-SITE DISPOSAL PATTERNS IN CALIFORNIA
UNIVERSITY OF CALIFORNIA, DAVIS (UCD), 1982

In contrast to the generator survey and theoretical inventories previously discussed, this one was produced using composition and quantity data from waste hauler manifests. Some 12,000 manifests were examined, covering one and one-half years haulage, and the wastes were classified into the 94 "UCD" waste categories. These categories of waste are similar to those in the New York inventory, discussed below. With this data, an estimation of waste quantities shipped, according to generator location, disposal method, and industry, has been compiled. The outstanding feature of the inventory is that it contains only hauled wastes; those that are not hauled but are disposed or recovered on-site are not included. This eliminates many large-volume wastes. Fly ash or slag, for instance, and wastes discharged to sewer or water bodies are not represented. Wastes currently being landfarmed on site would not be identified either, making such an inventory less valuable for estimating waste volumes for purposes of this study. However, for those wastes included, waste generation-per-employee quantities may be calculated for relevant SIC classes and these used for comparison with industry in other jurisdictions.

A summary of hazardous waste generation observed is given in the following table.

TOTAL HAZARDOUS WASTE GENERATION IN CALIFORNIA (SEPTEMBER 1979 AND MAY 1980) BY TYPE

UCD NO.	UCD WASTE TYPE	TON	PERCENT
111	Acidic Solution with Heavy Metals	12,383	5.47
112	Acidic solution with Other Metals and Non-Metals	1,755	0.78
113	Other Acidic Solution	4,120	1.82
121	Alkaline Solution with Heavy Metals	2,965	1.31
122	Alkaline Solution with Other Metal and Non-Metals	6,427	2.84
123	Other Alkaline Solution	3,864	1.71
131	Spent Etching/Plating Solution, Acidic	972	0.43
132	Spent Etching/Plating Solution, Alkaline	878	0.39
133	Spent Pickle Liquor	376	0.17
141	Aqueous Solution with Heavy Metals	4,020	1.78
142	Aqueous Solution with Other Metals	3,686	1.63
143	Aqueous Solution with Reactive Anions*	9,965	4.40
144	Other Aqueous Solutions	766	0.34
145	Brine	5,982	2.64
151	Inorganic Solids	252	0.11
153	Inorganic (Solid) Chemicals	90	0.04
161	Asbestos and Wastes	5,596	2.47
162	Aluminum or Tin Dross	2	0.00
165	Spent Catalyst, Including FCC Wastes	2,722	1.20
167	Unidentified Inorganic Wastes	257	0.11
211	Halogenated Solvent with Heavy Metals	75	0.03
212	Halogenated Solvent with Other Metals	12	1.01
213	Halogenated Solvents	1,154	0.51
214	Non-Halogenated Solvent with Heavy Metals	254	0.11
215	Non-Halogenated Solvent with Other Metals	206	0.09
216	Non-Halogenated Solvents	1,593	0.70
217	Unspecified Solvents	557	0.25
221	Organic Liquid with Halogens and Metals (all kinds)	433	0.19
222	Organic Liquid with Halogens only	443	0.20
223	Organic Liquid with Heavry Metals only	227	0.10
224	Other Organic Liquids	580	0.26
225	Aqueous Solution with Organic Residues <10%	15,611	6.89
227	Aqueous Solution with Organic Residues >10%	2,496	1.10
231	Organic Solid with Halogens	20	0.01
232	Organic Solid without Halogens	96	0.04
241	Pesticides and Wastes	11,580	5.11

TOTAL HAZARDOUS WASTE GENERATION IN CALIFORNIA (SEPTEMBER 1979 AND MAY 1980) BY TYPE

UCD NO.	UCD WASTE TYPE	TON	PERCENT
242	PCB & Material Containing PCB	229	0.10
243	Pharmaceuticals and Wastes	6	0.00
244	Photochemicals and Wastes	245	0.11
245	Off Specified or Aged Organics	13	0.01
248	Non-Halogenated Still Bottoms	81	0.04
251	Tannery Wastes	1,850	0.82
253	Detergents and Soap	355	0.16
254	Adhesive and Glue	99	0.04
255	Unidentified Organic Wastes	30	0.01
261	Polymeric Resin Wastes	673	0.30
262	Latex and Wastes	323	0.14
263	Other Pulymeric Material and Wastes	1,603	0.71
271	Sewage Sludge	164	0.07
272	Other Biological Wastes	249	0.11
281	Waste Oil and Mixed Oil	1,267	0.56
282	Oily Tank Bottoms	664	0.29
283	Mixtures of Oil, Mud/Sediment and Water	7,914	3.49
284	Acidic Oily Sludge	540	0.24
285	Alkaline Oily Sludge	1,891	0.84
286	API Separator Sludge	1,921	0.85
287	Oily Sludge	4,050	1.79
288	Oily Sludge with Heavy Metals	795	0.35
289	Mixtures of Oil/Gas with Water	4,817	2.13
412	Filter Press Cake/Sludge	144	0.06
413	Scrubber Sludge	130	0.06
416	Ink Sludge	192	0.08
417	Alum and Gypsum Sludge	26	0.01
431	Heavy Metal Sludge	10,752	4.75
433	Others Metals Sludge	3,199	1.41
441	Lime Sludge	3,623	1.60
442	Phosphate Sludge	19	0.01
443	Sulfur Sludge	5,451	2.41
445	Plating/Metal Finishing Sludge	1,046	0.46
446	Degreasing Sludge	22	0.01
447	Tetraethyl Lead Sludge	3,137	1.39
453	Paper Pulp/Sludge	670	0.30
454	Paint Sludge	6,135	2.71
455	Dye Sludge	9	0.00
456	Other Waste Treatment Sludge	464	0.21

TOTAL HAZARDOUS WASTE GENERATION IN CALIFORNIA (SEPTEMBER 1979 AND MAY 1980) BY TYPE

UCD NO.	UCD WASTE TYPE	TON	PERCENT
457	Sludges with Organic Residues	1,268	0.56
509	Gas Cylinders or Containers	3	0.00
510	Flue Gas Scrubber Liquid	13,079	5.78
511	Rinse Water and Waste Waer	4,002	1.77
512	Spill Clean-Up	61	0.03
513	Laboratory Waste Chemicals	446	0.20
514	Contaminated Soil and Sand	3,659	1.62
515	Drilling Mud	21,797	9.63
518	Dust Collector Waste	29	0.01
519	Fly Ash, Retort Ash	439	0.19
521	Spent Cartridge Filters	10	0.00
523	Tank Bottom Sediments	9,115	4.02
524	Chemical Toilet Waste	160	0.07
525	Metal Dust and Machining Waste	156	0.07
526	Cannery Waste	122	0.05
527	Mud/Sediment and Water	3,315	1.46
531	Contaminated Rags, Pellets	211	0.09
532	Contaminated Equipment, Containers	778	0.34
535	Totally Unspecified Wastes	499	0.22
	TOTAL	226,451	100.00

* 143: 17.1% Cyanide ion, 16.1% Sulphide Ion
41.5% Fluoride Ion, 4.4% Hypochlorite Ion
19.5% Bromate Ion, and 1.4% Miscellaneous.

APPENDIX 10

REPORT TO THE HAZARDOUS WASTE MANAGEMENT COUNCIL ON CURRENT HAZARDOUS WASTE GENERATION IN CALIFORNIA DEPARTMENT OF HEALTH SERVICES, CALIFORNIA, 1982

Subsequent to the "hauled waste" inventory, this study dealt with non-hauled wastes as well.

Their total estimate was 44 million tons.

The distribution is shown in the Table below. Aqueous solutions represent about 95%, and the bulk of this is discharged to sewers and surface waters. This inventory has thus a different perspective from that of the California hauled waste study and the OWMC inventory (wastes requiring treatment).

HAZARDOUS WASTE RELATED ACTIVITIES BY UCD TYPES

UCD NO.	UCD WASTE TYPE	TON	PERCENT
000	Toxic	4,133	0.01
001	Ignitable	53,510	0.12
002	Corrosive	5,647,494	12.68
003	Reactive	3,697	0.01
004	Ignitable and Reactive	49	0.00
005	Corrosive and Reactive	34,397	0.08
006	Ignitable, Corrosive and Reactive	30	0.00
007	Ignitable and Corrosive	3,075	0.01
008	Toxic and Ignitable	2,185	0.00
111	Acidic Solution with Heavy Metals	1,197,460	2.69
112	Acidic Solution with other Metals and Non-Metal	2,820	0.01
113	Other Acidic Solution	1,058,334	2.38
121	Alkaline Solution with Heavy Metals	9,888	0.02
122	Alkaline Solution with other Metal	3,380	0.01
123	Other Alkaline Solution	9,551	0.02
131	Spent Etching/Plating Solution, Acidic	198,803	0.45
132	Spent Etching/Plating Solution, Alkaline	532,030	1.19
141	Aqueous Solution with Heavy Metals	5,479,945	12.30
142	Aqueous Solution with Other Metals	584	0.00
143	Aqueous Solution with Cyanide Anion	114,424	0.26
144	Other Aqueous Solutions	868	0.00
151	Inorganic Solids	65,180	0.15
153	Inorganic (Solid) Chemicals	1,251	0.00
161	Asbestos and Wastes	1,021	0.00
211	Halogenated Solvent with Heavy Metals	1	0.00
213	Halogenated Solvents	31,524	0.07
215	Non-Halogenated Solvent with other Metals	755	0.00
216	Non-Halogenated Solvents	42,963	0.10
217	Unspecified Solvents	15	0.00
221	Organic Liquid with Halogens and Metals (all kinds)	3	0.00
222	Organic Liquid with Halogens only	7,017	0.02
224	Other Organic Liquids	2,044	0.00
225	Aqueous Solution with Organic Residues <10%	1,532,664	3.44
227	Aqueous Solution with Organic Residues >10%	1	0.00
232	Organic Solid without Halogens	41	0.00
241	Pesticides and Wastes	123,723	0.28
242	PCB and Material Containing PCB	13	0.00
244	Photochemicals and Wastes	28,701	0.06
245	Off Spec. or Aged Organics	322	0.00

HAZARDOUS WASTE RELATED ACTIVITIES BY UCD TYPES

UCD NO.	UCD WASTE TYPE	TON	PERCENT
251	Tannery Wastes	150	0.00
254	Adhesive and Glue	103	0.00
261	Polymeric Resin Wastes	581	0.00
263	Other Polymeric Materials and Wastes	2,094	0.00
271	Sewage Sludge	17	0.00
281	Waste Oil and Mixed Oil	7,198	0.02
282	Oily Tank Bottoms	240	0.00
283	Mixtures of Oil, Mud/Sediment and Water	1,840	0.00
286	API Separator Sludge	313,662	0.70
287	Oily Sludge	19,181	0.04
288	Oily Sludge with Heavy Metals	898	0.00
289	Mixtures of Oil/Gas with Water	156,004	0.35
412	Filter Press Cake/Sludge	350	0.00
413	Scrubber Sludge	200,000	0.45
416	Ink Sludge	1,284	0.00
431	Heavy Metal Sludge	52,697	0.12
433	Other Metal Sludges	6,501	0.01
441	Lime Sludge	1,800	0.00
442	Phosphate Sludge	5	0.00
445	Plating/Metal Finishing Sludge	20	0.00
447	Tetraethyl Lead Sludge	6,664	0.01
454	Paint Sludge	293,190	0.66
456	Other Waste Treatment Sludge	32	0.00
457	Sludges with Organic Residues	16,338	0.04
511	Rinse Water and Waste Water	27,187,832	61.04
512	Spill Clean Up	50	0.00
513	Laboratory Waste Chemicals	26	0.00
518	Dust Collector Waste	4,570	0.01
521	Spent Cartridge Filters	109	0.00
525	Metal Dust and Machining Waste	1,064	0.00
531	Contaminated Rags, Pellets	43	0.00
532	Contaminated Equipment, Containers	2,574	0.01
535	Totally Unspecified Wastes	250	0.00
536	HF Solutions	10,670	0.02
538	Hypochlorite Solution/Hypochlorite Ion Solution	40,000	0.02
611	Residual Gases in Containers	6	0.00
612	Halogenated Still Bottoms	572	0.00
613	Explosives	153	0.00
614	Waste Solids Containing Barium	19,890	0.04
	TOTAL	44,542,551	100.00

APPENDIX 11
INDUSTRIAL HAZARDOUS WASTE GENERATION IN NEW YORK
DIVISION OF SOLID WASTE MANAGEMENT, NEW YORK, 1979

A very complete work, this inventory is compiled from an intensive survey of New York's waste generating industries. Of New York's 4,000 potential hazardous waste generators "approximately 1,170 companies were inventoried, including all of the major hazardous waste producers".

Fly ash, slag, foundry sandy, brine (from salt mining) certain inorganic alkaline waste waters, and certain contaminated packagings were not inventoried. Where waste generation was known to be proportional to the number of production employees, (e.g. non-electrical machinery) major waste generators were identified by this criterion. Industries with high potential for hazardous waste production, such as the chemical and primary metal industries, were considered to warrant surveying most companies, large or small. Although the survey covered 20% to 25% of establishments of interest, the number of employees covered ranged from 35% to 100% within industries, averaging 73%. Extrapolations from the survey results by a waste-per- employee factor should then be very reliable; they indicate that the surveyed plants produce +90% of the State's hazardous wastes.

Data collection was by mail-in questionnaire plus interview; the response rate was very high, 98%. The waste generation is summarized in Table 6. Data from this survey have been used as the basis for waste generation estimates in other areas.

HAZARDOUS WASTE GENERATION BY SIC GROUP
NEW YORK

HAZARDOUS WASTE GENERATION BY TYPE
1141 TOTAL COMPANIES SURVEYED
789 TOTAL COMPANIES WITH AT LEAST ONE HAZARDOUS WASTE STREAM

TYPE	DESCRIPTION	NO. OF WASTE STREAMS	GALLONS	TONS
INORGANICS				
Acids				
101	Acid Solutions-Heavy Metals	40	1,713,219	49
102	Acid Solutions-Non-Metals	1	720	0
103	Acid Solutions-Other Metals	7	126,213	0
105	Other Acid Solutions	71	6,026,024	58,003
106	Spent Etchant	30	616,041	0
107	Spent Pickle Liquor	10	12,499,117	10,577
Alkalies				
112	Alkali Solution-Heavy Metals	8	235,446	25
113	Alkaline Solution-Non-Metals	5	30,860	0
114	Alkali Solution-Other Metals	3	22,750	0
115	Cyanide Solution	21	34,915	29
116	Other Alkaline Solutions	40	2,043,569	2
117	Spent Etchant	16	623,022	0
Inorganic Liquids and Solids				
121	Non-Solvent Inorganic Liquid	22	7,586,326	2,006
122	Inorganic Liquid-Heavy Metal	16	815,882	10
123	Inorganic Liquid-Other Metal	1	22,500	0
124	Other Inorganic Solids	22	0	12,225
125	Inorganic Gases	1	0	375
ORGANICS				
Solvents				
301	Halogen Solvent-Heavy Metals	3	4,535	0
302	Halogen Solvent-Heavy Metals	2	2,000	0
303	Other Halogenated Solvents	110	982,599	392
304	Non-Halogenated Solvents	79	14,239,587	89
305	Other Solvent-Heavy Metal	3	34,435	0
307	Unknown Solvent	5	12,655	0
310	Mixture of Solvents	170	30,557,445	20,020

HAZARDOUS WASTE GENERATION BY SIC GROUP
NEW YORK

HAZARDOUS WASTE GENERATION BY TYPE
1141 TOTAL COMPANIES SURVEYED
789 TOTAL COMPANIES WITH AT LEAST ONE HAZARDOUS WASTE STREAM

TYPE	DESCRIPTION	NO. OF WASTE STREAMS	GALLONS	TONS
Organic Liquids and Solids				
311	Halogenated Organic Liquids	37	3,697,965	5,107
313	Halogen Organic Liquids-Other Metals	1	12,000	0
314	Other Organic Liquids	34	7,271,205	4,140
315	Organic Liquid-Heavy Metal	1	200	0
317	Halogenated Organic Solids	7	38,365	120
318	Other Organic Solids	3	2,200	1,353
Sludges				
501	Ammonium Thiosulfate Sludge	1	0	53
502	Degreasing Sludge	8	11,635	0
503	Descaling Sludge	2	14,950	0
504	Drag-Out Sludge	7	1,159,800	286
505	Dye Solids and Sludges	2	9,255	0
506	Filter Press Sludge or Solid	26	28,600	12,560
507	Graphite or Carbon Sludge	1	0	2,000
508	Heavy Metal Sludge	108	10,776,711	19,106
509	Ink Solids and Sludges	18	58,075	10
510	Lime Sludge	6	404,000	2,638
511	Metal Finishing Sludge	55	318,940	8,951
512	Oil Sludge	4	268,150	0
513	Paint Solids and Sludges	98	1,005,849	2,134
514	Paper Sludge	1	84,000	0
516	PCB Solid or Sludge	6	3,467	1
517	Phenolic Solid or Sludges	9	22,825	3,725
520	Scrubber Sludge	7	151,770	320
521	Tetraethyl Lead Sludge	2	0	4
522	Waste Water Treatment Sludge	47	11,201,022	205,568
523	Brine Sludge	6	532,894	32,505
524	Phosphate Sludge	3	148,750	0
525	API Separator Sludge	3	518,000	0
526	Sulfur Sludge	2	135,000	0
528	Copper Mud	3	0	61
529	Silicon Tetrachloride Sludge	2	0	136
599	Other Sludge	3	136,000	15

HAZARDOUS WASTE GENERATION BY SIC GROUP
NEW YORK

HAZARDOUS WASTE GENERATION BY TYPE
1141 TOTAL COMPANIES SURVEYED
789 TOTAL COMPANIES WITH AT LEAST ONE HAZARDOUS WASTE STREAM

TYPE	DESCRIPTION	NO. OF WASTE STREAMS	GALLONS	TONS
Miscellaneous				
601	Asbestos	7	0	7,921
602	Dust Collector Waste	58	2,325	14,942
603	Boiler Wash	5	717,900	0
605	Brine Solutions	3	76,000	90
606	Broken Fluorescent Tubes	2	7,975	7
607	Contaminated Equipmnt	6	0	2,072
608	Contaminated Containers	31	390	9,658
610	Contaminated Pallets	1	60	0
611	Contaminated Soil	12	250,500	11,702
612	Non-Emulsified Waste Oil	253	9,743,937	2
613	Emulsified Oil	90	5,610,497	0
614	Epoxy Resin Waste	3	14,850	1
615	Epoxy Waste	1	60	0
616	Explosives	1	0	3
617	Fly Ash	5	600	14,039
618	Grease	2	220	0
619	Halogenated Still Bottoms	22	299,110	36
620	Halogenated Tank Residue	1	700	0
621	Lagoon Bottoms	7	1,902,405	101
622	Lagoon Tops	4	64,110	0
623	Low-Level Radioactive Waste	15	26,040	205
625	Magnesium Dust or Solid	2	27,500	0
628	Lab Chemicals	46	193,798	1,064
629	Non-Halogenated Still Bottom	23	3,067,600	471
630	Non-Halogenated Tank Residue	22	356,310	530
631	Off-Spec Chemicals	12	43,590	194
632	Off-Spec Pesticides	7	0	107
633	Off-Spec Pharmaceuticals	30	3,855	1,912
634	Off-Spec Paint	4	270	181
635	Mineral Oil	5	107,320	0
636	Photographic Chemical Waste	35	1,126,245	3,874
637	Phenolic Resin Waste	5	66,828	900
638	Spill Clean-Up	19	65,980	1,001
639	Scrap Batteries	4	2,640	53

HAZARDOUS WASTE GENERATION BY SIC GROUP
NEW YORK

HAZARDOUS WASTE GENERATION BY TYPE
1141 TOTAL COMPANIES SURVEYED
789 TOTAL COMPANIES WITH AT LEAST ONE HAZARDOUS WASTE STREAM

TYPE	DESCRIPTION	NO. OF WASTE STREAMS	GALLONS	TONS
641	Solder Flux or Wave Oil	10	30,948	65
642	Spent Activated Carbon	4	0	864
643	Spent Cartridge Filters	4	10,000	37
644	Spent Catalyst	11	0	5,130
645	Tannery Waste	2	1,801,490	0
647	Waste Tar	1	0	8
649	Textile Coating Solutions	7	569,600	0
650	Rinse Water and Waste Waters	38	22,895,755	0
651	Mixed Oils	43	1,724,846	0
652	Retort Ash	1	0	9
653	Other Mixed Waste	116	1,829,421	20,041
654	Peroxide Waste	1	0	0
655	Lab Animals and Human Blood	8	15,020	306
656	Sewage Sludge	2	454,000	0
657	Obsolete or Rejected Goods	7	30,065	618
658	Polyester Resin	2	660	250
659	Fermentation Cake	2	0	6,600
660	Waste Gelatins	1	0	85
661	Aluminum or Tin Dross	5	0	5,320
662	Others	2	40,000	8,748
	TOTAL	2,211	169,422,908	523,742

MAJOR VOLUMES OF HAZARDOUS WASTES BY TYPE IN NEW YORK

TYPE	APPROXIMATE HAZARDOUS WASTE GENERATION (TONNES)	% OF TOTAL FROM SURVEY
Acids	86,363	7.7
Alkalies	10,909	1.0
Pickle Liquor	66,364	5.9
Etching Solution	5,000	0.5
Halogenated Solvents	4,545	0.4
Other Solvents	230,454	20.6
Heavy Metal Sludges	65,909	5.8
Waste Water Treatment Sludges	238,181	21.3
Other Sludges	75,455	6.8
Waste Oils	71,364	6.4
Still Bottoms	15,000	1.4
Photographic Chemicals	8,636	0.8
Rinse Water and Other Waste Waters	104,091	9.3
SUBTOTAL	982,272	
Leather Tanning Wastes	54,445	4.9
TOTAL*	1,036,717	92.8

* Is @ 92% of Total Hazardous Waste Generation from Survey.

APPENDIX 12

HAZARDOUS WASTE RELATED ACTIVITIES BY UCD TYPES

TONNES/YEAR

UDC #	Waste Types	Newfoundland	New Brunswick	Ontario (OWMC)	Saskatchewan (Dillon)	Saskatchewan (Reid/Crowther)	Northwest Canada (Reid/Crowther)	North and West Canada (Wardrop)	California Total	California Hauled	New York
000	Toxic								3,757		
001	Ignitable								48,645		
002	Corrosive								51,134,086		
003	Reactive								3,055		
004	Ignitable and Reactive								45		
005	Corrosive and Reactive								31,270		
006	Ignitable, Corrosive and Reactive								27		
007	Ignitable and Corrosive								2,795		
008	Toxic and Ignitable								1,986		
111	Acidic sol'n with heavy metals	130	38		57.6	40	1,540		1,088,600	16,598	86,363
112	Acidic sol'n w/other metals and non-metal							26,000,000	2,564		
113	Other acidic sol'n			574,300	240	2,200	50,910		962,121		
121	Alkaline sol'n with heavy metals				12,240	10	170		8,989		10,909
122	Alkaline sol'n w/other metal and non-metal							103,000,000	3,073	12,051	
123	Other alkaline sol'n										
131	Spent etching/plating sol'n, acidic		8			3,606	16,510		8,683		
132	Spent etching/plating sol'n, alkaline	2,119			16.5				180,730	2,024	71,364
141	Aq. sol'n with heavy metals								483,663		
142	Aq. sol'n with other metals								4,981,768		
143	Aq. sol'n with cyanide anion			34,800					531	22,199	
144	Other aqueous sol'n							154,000,000	7,898		
151	Inorganic solids								59,255	311	

APPENDIX 12
HAZARDOUS WASTE RELATED ACTIVITIES BY UCD TYPES
TONNES/YEAR
(continued)

UDC #	Waste Types	Newfoundland	New Brunswick	Ontario (OWMC)	Saskatchewan (Dillon)	Saskatchewan Reid/Crowther	Northwest Canada Reid/ Crowther	North and West Canada Wardrop	California Total	California Hauled	New York
153	Inorganic (solid chemicals								1,137		
161	Asbestos and wastes				4.0	10			928	7,797	
211	Halogenated solvent w/heavy metals						3,820		1	1,128	4,545
213	Halogenated solvents					200	3,900		28,658		230,454
215	Non-halogenated solvent w/other metals	214		42,100	370	20		27,000	686	2,373	
216	Non-halogenated solvents		106				6,820		39,057		
217	Unspecified solvents								14		
221	Org. liq. w/halogens & metals (all kind)								3		
222	Org. liq. w/halogens only								6,379	1,530	
224	Other organic liquids						30	30	1,858		
225	Aq. sol'n with organic residues <10%			700					1,393,330	16,461	
227	Aq. sol'n with organic residues >10%								1		
232	Org. solid w/o halogens				0.9				37	105	
241	Pesticides and wastes	34		600	17.3	50	310	140,000	112,475	16,527	
242	PCB and material containing PCB		17	200	98.8		30	23	12	229	
244	Photochemicals and wastes		715		45.1	1,800	4,420	4,500	26,092		8,636
245	Off spec. or aged organics				876				293	2,435	
251	Tannery wastes					12,800	25,000		136		54,445
254	Adhesive and glue								94		
261	Polymeric resin wastes								528	2,363	

APPENDIX 12
HAZARDOUS WASTE RELATED ACTIVITIES BY UCD TYPES
TONNES/YEAR
(continued)

UDC #	Waste Type:	Newfoundland	New Brunswick	Ontario (OWMC)	Saskatchewan (Dillon)	Saskatchewan Reid/Crowther	Northwest Canada Reid/ Crowther	North and West Canada Wardrop	California Total	California Hauled	New York
263	Other polymeric material & wastes				47.6	240	1,710		1,904		
271	Sewage sludge								15	375	
281	Waste oil and mixed oil			51,000	3,763	12,500	68,500	2,022,000	6,543		
282	Oily tank bottoms								218		
283	Mixtures of oil, mud/sediment & water	2,438		221,400	1,349				1,673		
286	API separator sludge								285,147	21,690	71,364
287	Oily sludge								17,437		
288	Oily sludge w/heavy metals								816		
289	Mixtures of oil/gas w/water			69,000					141,822		
412	Filter Press Cake/ Sludge								318	447	
413	Scrubber sludge								181,818		
416	Ink sludge				9.38	560	10,520	450	1,167		
431	Heavy metal sludge			246,800				68,000	47,906	12,683	65,909
433	Other metal sludges								5,910		
441	Lime sludge								1,636		
442	Phosphate sludge						50		5		
445	Plating/metal finishing sludge								18	14,717	
447	Tetraethyl Lead Sludge							190	6,058		
454	Paint sludge	12	47	50,000	63.6	80	1,380	4,400	266,536		74,555
456	Other waste treatment sludge								29		
457	Sludges with organic residues		49	47,100				2,300	14,853		
511	Rinse water and waste water		24						24,716,211	15,528	104,091

APPENDIX 12
WASTE GENERATED BY UCD TYPES
(concluded)

UDC #	Waste Types	Newfoundland	New Brunswick	Ontario	Saskatchewan (Dillon)	Saskatchewan Reid/Crowther	Northwest Canada Reid/ Crowther	North and West Canada Wardrop	California Total	California Hauled	New York
512	Spill clean-up	106		7,600	81	4,000	11,010	3,000,000,000	45		
513	Laboratory waste chemicals					9,400	39,600		24		
518	Dust collector waste				3,000	30	140		4,155		
521	Spent cartridge filters								99	8,989	
525	Metal dust and machining waste								967		
531	Contaminated rags, pellets								39		
532	Contaminated equipment containers					10	910		2,340		
535	Totally unspecified wastes							2,700,000	225		
536	HF solutions								9,700		
538	Hypochorite Soln/Hypo-chlorite ion soln.								36,000		
611	Residual gases in containers								5		
612	Halogenated still bottoms								520		
613	Explosives								139		
614	Waste Solids Containing barium								18,082		
	Drilling Mud							6,300,000	-	19,815	
	Tank Bottom Sediments	1,893				720	3,760	8,000	-	8,286	
	Hospital Wastes				88.5	930	3,240	2,170	-		
	Waste water Treatment Sludges								-		238,181
	Still Bottoms								-		
	Miscellaneous	277		144,700		150	1,770		-		15,000
	TOTAL	7,223	1,013	1,490,300	22,367	46,000	246,400	3,300,000,000	40,493,228	1,234,712	1,036,717

APPENDIX 13

HAZARDOUS WASTE

NA9301 The following spent halogenated solvents used in degreasing: tetrachloroethylene, trichloroethylene, methylene chloride, 1,1,1-trichloroethane, carbon tetrachloride, and chlorinated fluorocarbons; and sludges from the recovery of these solvents in degreasing operations.

NA9302 The following spent halogenated solvents: tetrachloroethylene, methylene chloride, trichloroethylene, 1,1,1-trichloroethane, chlorobenzene, 1,1,2-trichloro-1,2,2-trifluoethane, ortho-dichlorobenzene, and trichlorofluoromethane; and the still bottoms from the recovery of these solvents.

NA9303 The following spent non-halogenated solvents: xylene, acetone, ethyl acetate, ethyl benzene, ethyl ether, methyl isobutyl ketone, n-butyl alcohol, cyclohexanone, and methanol; and the still bottoms from the recovery of these solvents.

NA9304 The following spent non-halogenated solvents: cresols and cresylic acid, and nitrobenzene; and the still bottoms from the recovery of these solvents.

NA9305 The following spend non-halogenated solvents: toluene, methyl ethyl ketone, carbon disulphide, isobutanol, and pyridine; and the still bottoms from the recovery of these solvents.

NA9306 Waste water treatment sludges from electroplating operations except from the following processes: (1) sulphuric acid anodizing of aluminum; (2) tin plating on carbon steel; (3) zinc plating (segregated basis) on carbon steel; (4) aluminum or zinc-aluminum plating on carbon steel; (5) cleaning/stripping associated with tin, zinc and aluminum plating on carbon steel; and (6) chemical etching and milling of aluminum.

NA9307 Waste water treatment sludges from the chemical conversion coating of aluminum.

NA9308 Spent cyanide plating baths solutions from electroplating operations (except for precious metals electroplating spent cyanide plating bath solutions).

NA9309 Plating bath sludges from the bottom of plating baths from electroplating operations where cyanides are used in the process (except for precious metals electroplating bath sludges).

HAZARDOUS WASTE

NA3910	Spent stripping and cleaning bath solutions from electroplating operations where cyanides are used in the process (except for precious metals electroplating spent stripping and cleaning bath solutions).
NA9311	Quenching bath sludge from oil baths from metal heat treating operations where cyanides are used in the process (except for precious metals heat treating quenching bath sludges).
NA9312	Spent cyanide solutions from salt bath pot cleaning from metal heat treating operations (except for precious metals heat treating spent cyanide solutions from salt bath pot cleaning).
NA9313	Quenching waste water treatment sludges from metal heat treating operations where cyanides are used in the process (except for precious metals heat treating quenching waste water treatment sludges).
NA9314	Cyanidation waste water treatment tailing pond sediment from mineral metals recovery operations.
NA9315	Spent cyanide bath solutions from mineral metals recovery operations.
NA9316	Bottom sediment sludge from the treatment of waste waters from wood preserving processes that use creosote and/or pentachlorophenol.
NA9317	Waste water treatment sludge from the production of chrome yellow and orange pigments.
NA9318	Waste water treatment sludge from the production of molybdate orange pigments.
NA9319	Waste water treatment sludge from the production of zinc yellow pigments.
NA9320	Waste water treatment sludge from the production of chrome green pigments.
NA9321	Waste water treatment sludge from the production of chrome oxide green pigments (anhydrous and hydrated).
NA9322	Waste water treatment sludge from the production of iron blue pigments.

NA9323	Oven residue from the production of chrome oxide green pigments.
NA9324	Distillation bottoms from the production of acetaldehyde from ethylene.
NA9325	Distillation site cuts from the production of acetaldehyde from ethylene.
NA9326	Bottom stream from the waste water stripper in the production of acrylonitrile.
NA9327	Bottom stream from the acetonitrile column in the production of acrylonitrile.
NA9328	Bottoms from the acetonitrile purification column in the production of acrylonitrile.
NA9329	Still bottoms from the distillation of benzyl chloride.
NA9330	Heavy ends or distillation residues from the production of carbon tetrachloride.
NA9331	Heavy ends (still bottoms) from the purification column in the production of epichlorohydrin.
NA9332	Heavy ends from the fractionation column in ethyl chloride production.
NA9333	Heavy ends from the distillation of ethylene dichloride in ethylene dichloride production.
NA9335	Aqueous spent antimony catalyst waste from fluoromethanes production.
NA9336	Distillation bottom tars from the production of phenol/acetone from cumene.
NA9337	Distillation light ends from the production of phthalic anhydride from naphthalene.
NA9338	Distillation bottoms from the production of phthalic anhydride from naphthalene.
NA9339	Distillation light ends from the production of phthalic anhydride from ortho-xylene.
NA9340	Distillation bottoms from the production of phthalic anhydride from ortho-xylene.

HAZARDOUS WASTE

NA9341	Distillation bottoms from the production of nitrobenzene by the nitration of benzene.
NA9342	Stripping still tails from the production of methyl ethyl pyridines.
NA9343	Centrifuge and distillation residues from toluene disocyanate production.
NA9344	Spent catalyst from the hydrochlorinator reactor in the production of 1,1,1-trichloroethane.
NA9345	Waste from the product steam striper in the production of 1,1,1-trichloroethane.
NA9346	Distillation bottoms from the production of 1,1,1-trichloroethane.
NA9347	Heavy ends from the heavy ends column from the production of 1,1,1-trichloethane.
NA9348	Column bottoms or heavy ends from the combined production of trichloroethylene and perchloroethylene.
NA9349	Distillation bottoms from aniline production.
NA9350	Process residues from aniline extraction from the production of aniline.
NA9351	Combined waste water streams generated from nitrobenzene/aniline production.
NA9352	Distillation or fractionation column bottoms from the production of chlorobenzenes.
NA9353	Separated aqueous stream from the reactor product washing step in the production of chlorobenzenes.
NA9354	By-product salts generated in the production of MSMA and cacodylic acid.
NA9355	Waste water treatment sludge from the production of chlordane.
NA9356	Waste water and scrub water from the chlorination of cyclopentadiene in the production of chlordane.

HAZARDOUS WASTE

NA9357	Filter solids from the filtration of hexachlorocyclopentadiene in the production of chlordane.
NA9358	Vacuum stripper discharge from the chlordane chlorinator in the production of chlordane.
NA9359	Waste water treatment sludges generated in the production of creosote.
NA9360	Still bottoms from toluene reclamation distillation in the production of disulfoton.
NA9361	Waste water treatment sludges from the production of disulfoton.
NA9362	Waste water from the washing and stripping of phorate production.
NA9363	Filter cake from the filtration of diethylphosphorodithioic acid in the production of phorate.
NA9364	Waste water treatment sludge from the production of phorate.
NA9365	Waste water treatment sludge from the production of toxaphene.
NA9366	Untreated process waste water from the production of toxaphene.
NA9367	Heavy ends or distillation residues from the distillation of tetrachlorobenzene in the production of 2,4,5-T.
NA9368	2,6-Dichlorophenol waste from the production of 2,4-D.
NA9369	Untreated waste water from the production of 2,4-D.
NA9370	Waste water treatment sludges from the manufacturing and processing of explosives.
NA9371	Spent carbon from the treatment of waste water containing explosives.
NA9372	Waste water treatment sludges from the manufacturing, formulation and loading of lead-based initiating compounds.
NA9373	Pink/red water from TNT operations.
NA9374	Dissolved air flotation (DAF) float from the petroleum refining industry.

HAZARDOUS WASTE

NA9375	Slop oil emulsion solids from the petroleumn refining industry.
NA9376	Heat exchanger bundle cleaning sludge from the petroleum refining industry.
NA9377	API separator sludge from the petroleum refining industry.
NA9378	Tank bottoms (leaded) from the petroleum refining industry.
NA9379	Ammonia still lime sludge from coking operations.
NA9380	Emission control sludge from the primary production of steel in electric furnaces.
NA9381	Spent pickle liquor from steel finishing operations.
NA9382	Sludge from lime treatment of spent pickle liquor from steel finishing operations.
NA9383	Acid plant blowdown slurry/sludge resulting from the thickening of blowdown slurry from primary copper production.
NA9384	Surface impoundment solids contained in and dredged from surface impoundments at primary lead smelting facilities.
NA9385	Sludge from treatment of waste water and/or acid plant blowdown from primary zinc production.
NA9386	Electrolytic anode slimes/sludges from primary zinc production
NA9387	Cadmium plant leachate residue (iron oxide) from primary zinc production.
NA9388	Emission control sludge from secondary smelting.
NA9389	Waste leaching solution from acid leaching of emission control dust/sludge from secondary lead smelting.
NA9390	Brine purification muds from the mercury cell process in chlorine production, where separately prepurified brine is not used.
NA9391	Chlorinated hydrocarbon waste from the purification step of the diaphragm cell process using graphite anodes in chlorine production.
NA9392	Waste water treatment sludge from the mercury cell process in chlorine production.

HAZARDOUS WASTE

NA9393	Solvent washes and sludges, caustic washes and sludges, or water washes and sludges from cleaning tubs and equipment used in the formulation of ink from pigments, driers, soaps and stabilizers containing chromium and lead.
NA9394	Waste water treatment sludges generated during the production of veterinary pharmaceuticals from arsenic or organo-arsenic compounds.
NA9395	Distillation tar residues from the distillation of aniline-based compounds in the production of veterinary pharmaceuticals from arsenic or organo-arsenic compounds.
NA9396	Residue from the use of activated carbon for decolorization in the production of veterinary pharmaceuticals from arsenic or organo-arsenic compounds.
NA9397	Decanter tank tar sludge from coking operations.

APPENDIX 14

BASIS FOR LISTING HAZARDOUS AND SITE-SPECIFIC WASTE

NUMBER	CONSTITUENT CAUSING THE WASTE TO BE LISTED
NA9301	Tetrachloroethylene, methylene chloride, trichloroethylene, 1,1,1-trichloroethene, carbon tetrachloride, chlorinated fluorocarbons. (T)
NA9302	Tetrachloroethylene, methylene chloride, trichloroethylene, 1,1,1-trichloroethane, chlorobenzene, 1,1,2-trichloro-1,2,2-trifluoroethane, ortho-dichloroenzene, trichlorofluoromethane. (T)
NA9303	(I)
NA9304	Cresols and cresylic acid, nitrobenzene. (T)
NA9305	Toluene, methyl ethyl ketone, carbon disulphide, isobutanol, pyridine. (I, T)
NA9306	Cadmium, hexavalent chromium, nickel, cyanide (complexed). (T)
NA9307	Hexavelent chromium, cyanide (complexed). (T)
NA9308	Cyanide (salts). (R, T)
NA9309	Cyanide (salts). (R, T)
NA9310	Cyanide (salts). (R, T)
NA9311	Cyanide (salts). (R, T)
NA9312	Cyanide (salts). (R, T)
NA9313	Cyanide (complexed). (T)
NA9314	Cyanide (salts). (R, T)
NA9315	Cyanide (salts). (R, T)
NA9316	Pentachlorophenol, phenol, 2-chlorophenol, p-chloro-m-cresol, 2,4-dimethylphenyl, 2,4-dinitrophenol, trichlorophenols, tetrachlorophenols, creosote, chrysene, napthalene, fluoranthene, benzo(b)fluoranthene, benzo(a)pyrene, indeno(1,2,3-cd)pyrene, benz(a)anthracene, dibenz(a)anthracene, acenaphthalene. (T)

BASIS FOR LISTING HAZARDOUS AND SITE-SPECIFIC WASTE

NUMBER	CONSTITUENT CAUSING THE WASTE TO BE LISTED
NA9317	Hexavalent chromium, lead. (T)
NA9318	Hexavalent chromium, lead. (T)
NA9319	Hexavalent chromium. (T)
NA9320	Hexavalent chromium, lead. (T)
NA9321	Hexavalent chromium. (T)
NA9322	Cyanide (complexed) hexavalent chromium. (T)
NA9323	Hexavalent chromium. (T)
NA9324	Chloroform, formaldehyde, methylene chloride, methyl chloride, paraldehyde, formic acid. (T)
NA9325	Chloroform, formaldehyde, methylene chloride, methyl chloride, paraldehyde, formic acid, chloroacetaldehyde. (T)
NA9326	Acrylonitrile, acetonitrile, hydrocyanic acid. (R, T)
NA9327	Hydrocyanic acid, acrylonitule, acetonitrile. (R, T)
NA9328	Acetonitrile, Acrylamide. (T)
NA9329	Benzyl chloride, chlorobenzene, toluene, benzotrichloride. (T)
NA9330	Hexachlorobenzene, hexachlorobutadiene, carbon tetrachloride, hexachloroethane, perchloroethylene. (T)
NA9331	Epichlorohydrin, chloroethers, (bis(chloromethyl)ether and bis(2-chloroethyl)ether, trichloropropane, dichloropropanols. (T)
NA9332	1,2-dichloroethane, trichloroethylene, hexachlorobutadiene, hexachlorobenzene. (T)
NA9333	Ethylene dichloride, 1,1,1-trichloroethane, 1,1,2-trichloroethane, tetrachloroethanes, (1,1,2,2-tetrachlorethane and 1,1,1,2-tetrachloroethane) trichloroethylene, tetrachloroethylene, chloroform, vinyl chloride, vinylidene chloride. (T)

NUMBER	CONSTITUENT CAUSING THE WASTE TO BE LISTED
NA9334	Same as NA9333. (T)
NA9335	Antimony, carbon tetrachloride, chloroform. (T)
NA9336	Phenol, tars (polycyclic aromatic hydrocarbons). (T)
NA9337	Phthalic anhydride, maleic anhydride. (T)
NA9338	Phthalic anhydride, 1,4-naphthoquinone. (T)
NA9339	Phthalic anhydride, maleic anhydride. (T)
NA9340	Phthalic anhydride. (T)
NA9341	Meta dintrobenzene, 2,4-dinitrotoluene. (T)
NA9342	Paraldehyde, pyridines, 2-picoline. (T)
NA9343	Toluene diisocyanate, toluene-2-,4-diamine. (R, T)
NA9344	1,1,1-trichloroethane, vinyl chloride. (T)
NA9345	1,2-dichloroethane, 1,1,1-trichloroethane, vinyl chloride, vinylidene chloride, chloroform. (T)
NA9346	1,1,2-trichloroethane, 1,1,1,2-tetrachloroethane, 1,1,2,2-tetrachloroethane. (T)
NA9347	1,2-dichloroethane, 1,1,1-trichloroethane, 1,1,2-trichloroethane. (T)
NA9348	Hexachlorobenzene, hexachlorobutadiene, hexachloroethane, 1,1,1,2-tetrachloroethane, 1,1,2,2-tetrachloroethane, ethylene dichloride. (T)
NA9349	Aniline, diphenylamine, nitrobenzene, phenylenediamine. (T)
NA9350	Aniline, nitrobenzene, phenylenediamine. (T)
NA9351	Aniline, benzene, diphenylamine, nitrobenzene, phenylenediamine. (T)

NUMBER	CONSTITUENT CAUSING THE WASTE TO BE LISTED
NA9352	Benzene, dichlorobenzenes, trichlorobenzenes, tetrachlorobenzenes, pentachlorobenzenes, hexachlorobenzenes, benzyl chloride. (T)
NA9353	Benzene, monochlorobenzene, dichlorobenzenes, 2,4,6-trichlorophenol. (T)
NA9354	Arsenic. (T)
NA9355	Hexachlorocyclopentadiene. (T)
NA9356	Hexachlorocyclopentadiene. (T)
NA9357	Hexachlorocyclopentadiene. (T)
NA9358	Chlordane, heptachlor. (T)
NA9359	Creosote, chrysene, napthalene, fluoranthene, benzo(b)fluoranthene, benzo(a)pyrene, indeno(1,2,3-cd)pyrene, benzo(a)anthracene, dibenzo(a)anthracene, acenaphthalene. (T)
NA9360	Toluene, phosphorodithioic and phosphoro-thioic acid esters. (T)
NA9361	(Same as NA9360). (T)
NA9362	Phorate formaldehyde, phosphorodithioic and phosphorodithioic acid esters. (T)
NA9363	Phosphorodithioic and phosphorodithioic acid esters. (T)
NA9364	(Same as NA9362). (T)
NA9365	Toxaphene. (T)
NA9367	Hexachlorobenzene, orthodichlorobenzene. (T)
NA9368	2,4-dichlorophenol, 2,6-dichlorophenol, 2,4,6-trichlorophenol. (T)
NA9369	2,4-dichlorophenol, 2,4,6-trichlorophenol. (T)
NA9370	(R)
NA9371	(R)

NUMBER	CONSTITUENT CAUSING THE WASTE TO BE LISTED
NA9372	Lead. (T)
NA9373	(R)
NA9374	Hexavalent chromium, lead. (T)
NA9375	Hexavalent chromium, lead. (T)
NA9376	Hexavalent chromium. (T)
NA9378	Lead. (T)
NA9379	Cyanide, naphthalene, phenolic compounds, arsenic. (T)
NA9380	Hexavalent chromium, lead, cadmium. (T)
NA9381	Hexavalent chromium, lead. (C, T)
NA9382	Hexavalent chromium, lead. (C, T)
NA9383	Lead, cadmium. (T)
NA9384	Lead, cadmium. (T)
NA9385	Lead, cadmium. (T)
NA9386	Lead, cadmium. (T)
NA9387	Lead, cadmium. (T)
NA9388	Hexavalent chromium, lead, cadmium. (T)
NA9389	(T)
NA9390	Mercury. (T)
NA9391	Chloroform, carbon tetrachloride, hexachloroethane, trichloroethane, tetrachloroethylene, dichloroethylene, 1,1,2,2-tetrachloroethane. (T)
NA9392	Mercury. (T)
NA9393	Lead, hexavalent chromium. (T)
NA9394	Arsenic. (T)

NUMBER	CONSTITUENT CAUSING THE WASTE TO BE LISTED
NA9395	Arsenic. (T)
NA9396	Arsenic. (T)
NA9397	Phenol, naphthalene. (T)

APPENDIX 15
GROWING DEGREE DAYS

For purposes of estimating the effective growing season from the standpoint of temperature, the factor "degree-days above 5°C per year", or "growing degree-days" may be used. This is calculated by summing positive values of (daily mean temperature - 5°C) for the year. For example: on a day when the maximum temperature is 21°C and the minimum 9°C, the daily mean is 15°C and the number of growing degree-days for the day is 15 - 5 = 10. For days when the mean temperature is below 5°C, the number of growing degree-days is considered to be zero.

The number of growing degree days varies radically throughout Canada. The following table lists approximate ranges in each province.

GROWING DEGREE DAYS BY PROVINCE

Alberta	390 - 980
British Columbia	530 - 2400
Manitoba	560 - 1840
New Brunswick	1400 - 1800
Newfoundland	100 - 1300
Northwest Territories	0 - 1230
Nova Scotia	1400 - 1800
Ontario	1000 - 2600
Quebec	600 - 2100
Prince Edward Island	1600 - 1700
Yukon	400 - 1000

Canadian Climate Normals, Volume 3, 1982.
Canadian Climate Program, Environment Canada.

APPENDIX 16

SUMMARY OF PRECIPITATION DATA FOR CANADA

	Rainfall mm	Total Precipitation mm	Days with Rainfall	Greatest 24 hr. Rainfall mm
Alberta	230 - 400	300 - 850	32 - 88	39 - 213
British Columbia	250 - 4200	250 - 4200	36 - 233	21 - 363
Manitoba	270 - 490	400 - 600	32 - 83	42 - 193
New Brunswick	660 - 1100	900 - 1400	70 - 124	59 - 179
Newfoundland	550 - 1300	740 - 1470	55 - 143	56 - 157
Northwest Territories	0 - 300	60 - 660	10 - 56	14 - 87
Nova Scotia	800 - 1300	970 - 1500	78 - 161	70 - 238
Ontario	380 - 800	600 - 1100	62 - 117	43 - 148
Quebec	500 - 980	500 - 1300	62 - 122	39 - 206
Prince Edward Island	760 - 880	930 - 1170	80 - 124	57 - 164

Canadian Climate Normals, Volume 3, 1982.
Canadian Climate Program, Environment Canada.

APPENDIX 17

RAW WASTEWATER CHARACTERIZATION OF TOXIC POLLUTANTS FOR THE LEATHER TANNING AND FINISHING INDUSTRY (62)

	Mean Concentration* (ug/l)				
Toxic Pollutant	1	2	3	4	5
Metals and Inorganics					
Chromium	80,000	90,500	5,100	89,000	74,000
Copper	173	NA†	380	250	190
Cyanide	40	35	80	30	ND#
Lead	11,700	700	140	1,300	790
Nickel	40	22	61	45	15
Zinc	430	315	490	198	1,000
Phthalates					
Bis(2-ethylhexyl)phthalate	51	32	ND	ND	ND
Dimethyl phthalate	120	ND	ND	ND	ND
Nitrogen Compounds					
Benzidine	27	ND	ND	ND	ND
N-Nitrosodiphenylamine	ND	ND	ND	250	ND
Phenols					
2,4-Dichlorophenol	ND	114	ND	ND	ND
Pentachlorophenol	ND	6,200	1,500	ND	3,600
Phenol	3,700	2,900	9,000	3,200	6,200
2,4,6-Trichlorophenol	3,400	4,800	ND	570	3,300
Aromatics					
Benzene	15	10	10	10	80
Chlorobenzene	ND	10	ND	ND	ND
1,2-Dichlorobenzene	260	ND	126	ND	36
1,4-Dichlorobenzene	54	ND	20	ND	13
Ethyl Benzene	88	150	58	80	80
Nitrobenzene	430	ND	ND	ND	ND
Toluene	280	80	12	10	80
Polycyclic Aromatic Hydrocarbons					
Acenaphthene	32	ND	ND	ND	ND
Acenaphylene	16	ND	ND	ND	ND
Fluoranthene	ND	2	ND	ND	ND
Naphthalene	46	49	32	ND	27
Phenanthrene/Anthracene	94	56	8	120	120
Pyrene	ND	1	ND	ND	ND
Halogenated Aliphatics					
Chloroform	20	26	24	10	10
Dichlorobromomethane	10	ND	10	ND	10
1,1-Dichloroethane	20	ND	ND	ND	ND

(continued)

Toxic Pollutant	Mean Concentration* (ug/l) 1	2	3	4	5
1,2-Trans-Dichloroethylene	30	ND	ND	ND	ND
1,1,2,2-Tetrachloroethane	10	ND	10	ND	ND
Tetrachloroethylene	ND	ND	23	ND	40
1,1,2-Trichloroethane	10	ND	ND	ND	ND
1,1,1-Trichloroethane	ND	10	ND	ND	ND
Trichloroethylene	ND	ND	ND	ND	10

* 1 - Hair pulp/chrome tan/retan-wet finish subcategory.
  2 - Hair save/chrome tan/retan-wet finish subcategory.
  3 - Non-chrome tan/retan-wet finish subcategory.
  4 - Retan-wet finish subcategory.
  5 - No beamhouse subcategory.

† NA = Not analyzed.

ND = Not detected.

APPENDIX 18

SUMMARY OF FOUR SLUDGE ANALYSES FROM A TYPICAL LEATHER TANNERY

Parameter	Number of Analysis	Hair-Burn Sludges			Chrome Sludge			Mixed Sludge		
		Range	Mean	Median	Range	Mean	Median	Range	Mean	Median
Moisture %	4	40.3-70.2	55.7	48.9	62.1-68.6	65.4	65.5	59.0-66.0	61.8	61.1
pH	4	6.1-9.5	7.3	7.5	7.4-8.0	7.8	7.8	7.2-8.6	7.9	7.8
EC mmhos/cm	5	5.5-17.8	10.8	12.5	4.1-10.6	8.4	10.5	4.9-12.1	9.3	10.8
SAR	5	7.7-34.4*	18.5	12.4	1.4-18.8	12.8	18.3	6.4-22.6	19.2	19.4
TOC %	4	14.2-24.4	16.5	16.4	20.4-42.7	32.8	34.0	20.1-34.1	27.8	28.9
TKN %	4	2.2-4.0	3.49	3.87	2.92-4.48	3.8	3.90	3.18-4.06	3.68	3.75
NO_3-N mg/kg	4	ND-18.0	-	-	ND-3.5	-	-	ND-5.2	-	-
NH_4-N mg/kg	4	77.9-7,650	2,340	818	534-4,780	1,706	755	420-5,280	1,900	958
Metals mg/kg										
Ca	3	10,400-94,500*	38,600	10,860	4,230-51,500*	34,610	48,100	4,500-70,500*	37,030	36,100
Mg	3	620-3,400*	1,933	1,980	1,520-10,000*	5,590	5,150	1,220-7,600*	4,420	4,440
Na	3	4,900-25,000*	21,300	14,000	8,100-45,000*	14,370	10,000	8,850-32,500*	16,780	9,000
Cr	4	28.0-675	294	237	20,900-55,400	43,680	49,200	14,600-37,900	28,150	30,050
Cu	3	3.5-21.0	10.2	6.0	48.5-68.0	58.8	60	29.0-36.5	34.0	36.5
Hg	3	.0013-.016	.0019	.0027	.0022-.0031	.0027	.0027	.00075-.025	.009	.0011
Ni	3	8.4-24.0	14.1	10.0	12-32.0	24	28	9.0-26.0	17.3	17.0
Pb	4	13.0-29.0	22.4	22.5	95-320	224	240	60-270	165	165
Zn	3	44.0-400	170	65.0	101-420	218	133	70.5-250	141	103

* Extreme variation due to analytical method change.

APPENDIX 19

ORGANIC ANALYSIS OF SLUDGE FROM THE LEATHER TANNING INDUSTRY (65)

Organic Fraction	% of Total Extractable Organics
Aliphatic Hydrocarbons	
Volatile	3.6
Nonvolatile	32.0
Aromatic Hydrocarbons	
Volatile	1.4
Nonvolatile	9.0
Polar Hydrocarbons	
Volatile	0.5
Nonvolatile	54.0

* Based on 2,200 mg/l of solvent extractable organics.

APPENDIX 20

CONCENTRATIONS OF TOXIC POLLUTANTS FOUND IN PAINT FORMULATING RAW WASTEWATER (73,87)

Wastewater Parameter	EPA (1979) Average	EPA (1979) Median	Average EPA (1980) - 4 Plants
Conventional (mg/l)			
Biochemical oxygen demand	9,892	4,850	3,875
Chemical oxygen demand	54,956	39,000	78,000
Oil and grease	1,099	938	1,358
Total dissolved solids	10,619	4,300	18,750
Total organic carbon	10,601	8,500	29,000
Total solids	28,945	22,750	32,250
Total suspended solids	20,424	12,800	13,475
Total volatile solids	13,017	11,350	14,875
Total volatile suspended solids	7,789	7,600	9,250
pH	-	8	7.4
Inorganics (ug/l)			
Aluminum	196,758	100,000	149,250
Antimony	209	>25	23
Arsenic	286	69	NA
Barium	8,656	2,000	8,580
Beryllium	126	<10	<10
Boron	4,268	1,000	ND
Cadmium	524	<20	48
Calcium	2,277,000	281,000	595
Chromium	3,120	260	653
Cobalt	912	300	892
Copper	2,476	400	500
Cyanide	79	25	121
Iron	271,307	40,000	62,000
Lead	6,300	805	1,505
Magnesium	107,000	36,000	37
Manganese	2,901	886	1,554

(continued)

Wastewater Parameter	EPA (1979) Average	EPA (1979) Median	Average EPA (1980) - 4 Plants
Inorganics (continued)			
Mercury	5,161	500	3,518
Molybdenum	674	200	97
Nickel	1,350	<50	605
Selenium	165	<25	ND
Silver	15	<10	11
Sodium	397	205	238
Thallium	151	<10	<10
Tin	1,111	400	498
Titanium	16,677	7,000	5,758
Vanadium	409	<100	ND
Yttrium	206	<200	ND
Zinc	74,746	10,000	58,008
Organics			
2 Acrolein	10	<10	ND
4 Benzene	1,933	370	3,408
6 Carbon tetrachloride	3,770	14	ND
7 Chlorobenzene	1,405	56	ND
9 Hexachlorobenzene	92	92	ND
10 1,2-Dichloroethane	118	33	25
11 1,1,1-Trichloroethane	141	76	50
13 1,1-Dichloroethane	11	11	ND
14 1,1,2-Trichloroethane	568	<10	ND
15 1,1,2,2-Tetrachloroethane	20	20	ND
20 2-Chloronapthalene	10	<10	ND
21 2,4,6-Trichlorophenol	2,455	>2,455	ND
23 Chloroform	186	92	126
28 3,3'-Dichlorobenzidine	10	<10	ND
29 1,1-Dichloroethylene	138	23	ND

(continued)

Wastewater Parameter	EPA (1979) Average	EPA (1979) Median	Average EPA (1980) - 4 Plants
Organics (continued)			
30 1,2-Trans-Dichloroethylene	135	135	ND
31 2,4-Dichlorophenol	10	<10	ND
32 1,2-Dichloropropane	265	41	<10
33 1,3-Dichloropropylene	100	100	ND
38 Ethylbenzene	7,482	1,300	667
39 Fluoranthene	10	<10	ND
40 4-Chlorophenyl phenyl ether	266	266	ND
42 Di(2-Chloroisopropyl)ether	3,200	3,200	ND
43 Di(2-Chloroethoxy)methane	10	<10	ND
44 Methylene Chloride	31,878	620	2,349
48 Dichlorobromomethane	27	27	ND
55 Napthalene	2,950	54	ND
56 Nitrobenzene	100	110	ND
59 2,4-Dinitrophenol	173	160	ND
60 4,6-Dinitro-o-cresol	10	<10	ND
64 Pentachlorophenol	6,017	750	ND
65 Phenol	746	96	66
Total Phenol	260	125	358
66 Di(2-Ethylhexyl)phlatate	418	140	15
67 Butyl Benzyl Phthalate	474	44	ND
68 Di-n-Butyl Phthalate	5,745	160	106
70 Diethyl Phthalate	233	<10	ND
73 Benzo (a) Pyrene	10	<10	ND
78 Anthracene	10	<10	ND
85 Tetrachloroethylene	567	175	1,729
86 Toluene	17,966	2,500	1,660
87 Trichloroethylene	81	23	159
89 Aldrin	10	<10	ND

(continued)

Wastewater Parameter	EPA (1979) Average	EPA (1979) Median	Average EPA (1980) - 4 Plants
Organics (continued)			
90 Dieldrin	10	<10	ND
93 4,4'-DDE	10	<10	ND
94 4,4'-DDD	10	<10	ND
96 Beta-Endosulfan	10	<10	ND
99 Endrin Aldehyde	10	<10	ND
102 Alpha-BHC	10	<10	ND
103 Beta-BHC	10	<10	ND
104 Gamma-BHC	10	<10	ND
105 Delta-BHC	10	<10	ND

APPENDIX 21

CONCENTRATIONS OF TOXIC POLLUTANTS FOUND IN SLUDGES FROM THE PAINT FORMULATING INDUSTRY (73, 87)

Wastewater Parameter	EPA (1979) Average	EPA (1979) Median	Average EPA (1980) - 4 Plants
Conventional (mg/l)			
Biochemical oxygen demand	24,982	10,200	23,200
Chemical oxygen demand	171,641	130,000	160,000
Oil and grease	7,578	2,500	4,433
Total dissolved solids	13,122	9,800	17,200
Total organic carbon	35,126	29,500	32,000
Total solids	107,785	78,000	112,667
Total suspended solids	101,201	70,000	93,667
Total volatile solids	39,438	37,000	36,000
Total volatile suspended solids	23,002	14,133	27,467
pH		7	7.6
Inorganics (ug/l)			
Aluminum	867,154	600,000	783,333
Antimony	1,579	150	235
Arsenic	879	495	ND
Barium	9,831	4,345	18,000
Beryllium	192	20	20.1
Boron	2,965	2,000	NA
Cadmium	840	200	118
Calcium	2,870	914	2,034
Chromium	7,050	700	819
Cobalt	2,131	600	1,010
Copper	7,121	1,000	1,033
Cyanide	1,151	20	89
Iron	886,452	200,000	250,000
Lead	10,770	3,000	1,357
Magnesium	156	79	97
Manganese	7,249	5,000	4,890

(continued)

Wastewater Parameter	EPA (1979) Average	EPA (1979) Median	Average EPA (1980) - 4 Plants
Inorganics (continued)			
Mercury	15,061	640	38,348
Molybdenum	1,680	1,000	840
Nickel	10,443	200	894
Selenium	547	250	NA
Silver	22	10	14
Sodium	583	260	247
Thallium	967	400	NA
Tin	2,640	2,000	1,567
Titanium	38,345	20,000	38,333
Vanadium	891	400	NA
Yttrium	207	200	NA
Zinc	230,946	90,000	167,067
Organics			
4 Benzene	414	30	<10
6 Carbon tetrachloride	10	<10	ND
7 Chlorobenzene	176	176	ND
10 1,2-Dichloroethane	17	17	ND
11 1,1,1-Trichloroethane	866	14	<10
15 1,1,2,2-Tetrachloroethane	13	13	ND
21 2,4,6-Trichlorophenol	10	<10	ND
23 Chloroform	920	920	ND
29 1,1-Dichloroethylene	NA	NA	ND
31 2,4-Dimethylphenol	10	<10	ND
38 Ethylbenzene	14,277	237	62
44 Methylene Chloride	120,201	1,735	4,600
59 2,4-Dinitrophenol	18	<18	ND
64 Pentachlorophenol	346	125	ND
65 Phenol	325	150	340
Total Phenol	552	166	419

(continued)

Wastewater Parameter	EPA (1979) Average	EPA (1979) Median	Average EPA (1980) - 4 Plants
Organics (continued)			
66 Di(2-Ethylhexyl)phlatate	455	215	590
67 Butyl Benzyl Phthalate	10,410	1,412	ND
68 Di-n-Butyl Phthalate	3,622	70	250
70 Diethyl Phthalate	370	100	ND
79 Dimethyl phthalate	10	<10	ND
78 Anthracene	210	<210	ND
84 Pyrene	10	<10	ND
85 Tetrachloroethylene	2,142	170	30
86 Toluene	44,740	905	180
87 Trichloroethylene	39	<10	ND
89 Aldrin	10	<10	ND
96 Beta-Endosulfan	10	<10	ND
103 Beta-BHC	10	<10	ND

APPENDIX 22

MEDIAN CONCENTRATIONS OF TOXIC POLLUTANTS
FOUND IN STEAMING AND BOULTON SUBCATEGORY RAW WASTEWATER (88)

Toxic Pollutant	Steaming Process (ug/l)	Boulton Process (ug/l)
Metals		
Antimony	1.5	NA
Arsenic	24	NA
Beryllium	<10	NA
Cadmium	1	NA
Chromium	23	NA
Copper	165	NA
Lead	12.5	NA
Mercury	0.1	NA
Nickel	24	NA
Selenium	1	NA
Silver	<10	NA
Thallium	1	NA
Zinc	360	NA
Phthalates		
Bis(3-ethylhexyl phthalate)	126	433
Phenols		
2-Chlorophenol	15	<10
2,4-Dimethylphenol	1,300	<10
Pentachlorophenol	23,600	10
Phenol	16,000	71
2,4,6-Trichlorophenol	252	<10
Monocyclic Aromatics		
Benzene	1,050	<10
Ethylbenzene	380	<10
Toluene	500	<10

(continued)

Toxic Pollutant	Steaming Process (ug/l)	Boulton Process (ug/l)
Polycyclic Aromatic Hydrocarbons		
Acenaphthene	1,700	NA
Acenaphthylene	933	NA
Anthracene/Phenanthrene	6,720	920
Benzo (a) anthracene	157	NA
Benzo (a) pyrene	7	<10
Benzo (b) fluoranthene	<10	<10
Benzo (ghi) perylene	<10	<10
Benzo (k) fluoranthene	17	<10
Chrysene	98	NA
Dibenzo (ah) anthracene		
Fluoranthene	1,600	NA
Fluorene	2,310	NA
Indeno (1,2,3-cd) pyrene	<10	<10
Naphthalene	3,470	NA
Pyrene	1,100	NA
Halogenated Aliphatics		
Methyl Chloride	77	2,600

NA = Not Analyzed.